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AGE AND GROWTH OF LAKE TROUT, *SALVELINUS NAMAYCUSH* (WALBAUM), IN LAKE TAHOE[1]

JACK A. HANSON and ALMO J. CORDONE
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Ages of 2,873 lake trout collected at various times between 1938 and 1964 were determined from their scales. The average calculated lengths for ages 1 through 17 are: 4.6, 7.9, 9.9, 12.6, 15.0, 17.0, 18.9, 20.9, 22.8, 24.5, 26.3, 27.7, 28.4, 30.4, 32.4, 33.4, and 35.8 inches, respectively. The fork length—anterior scale radius relationship is described by the formula $Y = 2.33018 + 0.14283X$. Comparison of year classes indicates that growth has been relatively constant for 40 years. Annulus formation occurred from early February to mid-September. Growth continued all year, reaching a maximum between mid-June and the end of September. Growth was slow compared to that in most other large, oligotrophic lakes. The length-weight relationship is described by $W = 3.63591 + 3.17941 \log L$.

INTRODUCTION

The California Department of Fish and Game and the Nevada Fish and Game Commission initiated a joint study of Lake Tahoe in 1960. The primary objective was to find and test methods of creating an attractive fishery by increasing the yield to anglers and providing trophy trout. An essential part of this study was to determine ages and rates of growth of game fish species as a basis for evaluating the methods used. This paper presents results of the age and growth study of lake trout based on materials collected during the present and earlier investigations (Curtis, 1938; Fraser, 1950, 1951; Miller, 1951; Corlett and Wood, 1958).

The first recorded introduction of lake trout into Lake Tahoe was made in 1889 by the Nevada Fish and Game Commission (Miller and Alcorn, 1945). From this, and subsequent plants by California and Nevada, lake trout became established and have maintained themselves entirely by natural reproduction. They are now the dominant species in the lake, comprising almost 60% of the total catch (Weidlein, Cordone, and Frantz, 1965; Cordone and Frantz, 1966*a*, *b*).

For a physical description of Lake Tahoe see McGauhey et al. (1963).

ACKNOWLEDGMENTS

We thank Richard G. Miller for providing scales collected in 1938, 1939, and 1949, and Ray Corlett for providing the 1955 to 1958 materials. The 1938 and 1939 scale samples were obtained by John Ernest Pomin and Stanley Pomin, under the direction of Brian Curtis. Most of the 1949 scales were collected under Miller's guidance by Robert

[1] Submitted for publication October 1966. This work was performed as part of Dingell-Johnson Project California F-21-R and Nevada F-15-R, "Lake Tahoe Fisheries Study", supported by Federal Aid to Fish Restoration funds.

Pattison, George Hunter, Harry James, Waldo Gross, and a Mr. Shelley. Harold K. Chadwick programmed age and growth data processing and also offered much guidance and advice throughout the investigation. Ted C. Frantz contributed substantial samples collected in the 1960's. Allen F. Guenther spent many long hours preparing the materials for study and tabulating data. Valuable suggestions were tendered by Phillip H. Baker. Cliffa E. Corson drew the figures.

METHODS AND MATERIALS

Scales were obtained from angler-caught fish and fish taken by various collection methods periodically from 1938 through 1964. Several scales were taken from the area below the anterior part of the dorsal fin and just above the lateral line. All fish were measured to the nearest 0.1-inch fork length and weighed to the nearest 0.01 pound.

Two to four average-appearing scales from each fish were cleaned and mounted in clear Karo syrup on microscope slides. Slides were identified only by a field number, and all other data; i.e., length, sex, weight, and area of capture, were recorded elsewhere to avoid prejudice in interpreting year marks. All scales were examined at a magnification of 80X under a Silge and Kuhne Ortho-Illuminator B scale projector.

Ages were determined by counting annuli. A virtual annulus was credited at the edge of the scale for fish captured from January 1 until the annulus was revealed by new growth.

A Manila strip was placed along the medial anterior radius from the focus to the edge of the scale. The location of each annulus and the edge of the scale were marked on the strip and then measured to the nearest millimeter for back calculations and to establish a body length—anterior scale radius relationship. The date of capture was recorded on the strip before "reading" the scales, to facilitate recognition of new growth. Data were transferred to IBM punch cards and processed on a UNIVAC 1107 computer.

One reader determined the ages of 2,873 fish. Regardless of how difficult to interpret, no scales were rejected. A second reader independently examined a sample of 100, and agreed on the number and location of annuli in 41 cases. The two readings agreed completely or disagreed by only one annulus in 89 cases. Age frequency distributions from the two readings differed only slightly. Since no one-way bias was evident, ages of the remainder were determined by a single reading.

Cable (1956) demonstrated the validity of the scale method for lake trout.

APPEARANCE OF THE ANNULUS

Cable also established criteria for distinguishing annuli on lake trout scales. The three considered most significant for Lake Tahoe lake trout were: (i) crowding of the circuli and then an abrupt change to wider spacing; (ii) the formation of crude V's where the ends of circuli from the previous growing season are cut over by the first circulus of the new season; (iii) the occurrence of very fine, broken lines, especially at the first two or three annuli.

Annuli were most conspicuous in the antero lateral and postero lateral angles. Only annuli that could be traced around a substantial portion of the scale were considered valid year marks.

FORK LENGTH-ANTERIOR SCALE RADIUS RELATIONSHIP

Fork length and anterior scale radius, plotted on a scatter diagram (1960 through 1964 data), approached a straight-line relationship closely enough to justify fitting a straight-line regression by the method of least squares (Figure 1).

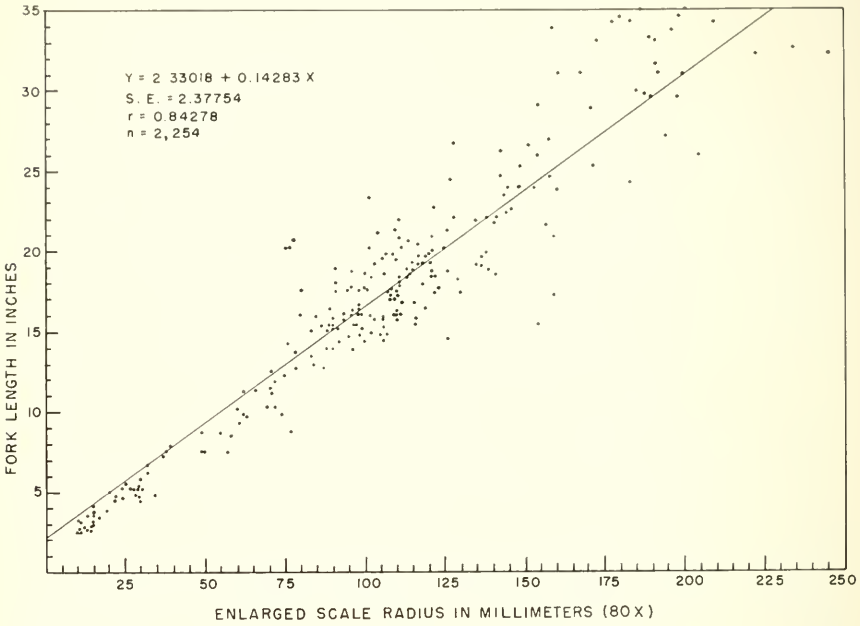

FIGURE 1—Relationship of anterior scale radius and fork length of Lake Tahoe lake trout. Points represent a random sample of individual fish collected from 1960 through 1964.

The formula $Y = 2.33018 + 0.14283X$ describes the relationship best where Y is the fork length in inches and X is the enlarged anterior scale radius in millimeters. The standard error of the estimate is 2.37754 and the correlation coefficient is 0.84278.

The Y-intercept of 2.33018 appears to approximate the size at scale formation reasonably well. Two fish, 1.5 and 1.7 inches, did not have scales, while specimens as small as 2.5 inches did.

CALCULATED GROWTH

Table 1 shows length frequencies by age groups of lake trout collected from 1938 through 1964. The wide range in length at each age and the great overlap of successive ages indicate a high degree of individual variation in growth rate. This is apparently characteristic of lake trout (Rawson, 1961; Kennedy, 1954).

TABLE 1

Length Frequencies by Age Groups of Lake Tahoe Lake Trout

Fork length class interval (inches)	Number of annuli																
	0	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII	XIV	XV	XVI	XVII
1.5–1.9	2																	
2.0–2.4	1																	
2.5–2.9	3	5																
3.0–3.4	1	5																
3.5–3.9	2	2																
4.0–4.4		1																
4.5–4.9		7	1															
5.0–5.4		3	5															
5.5–5.9			2															
6.0–6.4			1															
6.5–6.9			1															
7.0–7.4																		
7.5–7.9			4	3														
8.0–8.4				1														
8.5–8.9			1	4	1													
9.0–9.4				5	1													
9.5–9.9			1	10	3	1												
10.0–10.4				4	4		1											
10.5–10.9				2	2													
11.0–11.4				4	6	2	2											
11.5–11.9				2	13	5	1											
12.0–12.4				1	6	1												
12.5–12.9				1	5	7	1											
13.0–13.4				1	6	11	5											
13.5–13.9					9	14	12	2										
14.0–14.4					20	26	15	3										
14.5–14.9				1	6	40	20	6	2									
15.0–15.4					8	51	42	10	2				1					
15.5–15.9					7	39	11	23	3									
16.0–16.4					4	36	67	40	6									
16.5–16.9					3	31	65	45	6	1								
17.0–17.4					1	35	110	44	13	3								
17.5–17.9					5	18	70	57	28	1	1							
18.0–18.4						23	80	65	20	4		1						
18.5–18.9						11	54	69	23	6								
19.0–19.4						13	48	65	32	6	2	1						
19.5–19.9					1	2	34	39	27	7	1	2						
20.0–20.4						3	15	36	41	10	4							
20.5–20.9					1	1	17	35	23	4	3							
21.0–21.4						1	12	35	32	15	4	3						
21.5–21.9						1	6	17	25	21	5	2						
22.0–22.4						1	6	17	31	18	5	2	1	1				
22.5–22.9							1	8	16	16	4	2	1	1				
23.0–23.4						1	1	10	21	19	15	1	1					
23.5–23.9							2	5	14	16	13	3	1					
24.0–24.4							1	4	20	16	10	4						
24.5–24.9					1			1	13	9	9	4		1				
25.0–25.4							1	3	6	11	14	8		2	1			
25.5–25.9							1		8	4	6	5	1	2	1			
26.0–26.4								1	4	7	6	5	4					
26.5–26.9									2	4	5	7	1	1				
27.0–27.4							1		1	7	1	4	3	3	1			
27.5–27.9									1	4	4	1	3	2				
28.0–28.4							1	2	1		2	6	2	1		1		
28.5–28.9									3	1	1	2	3	1				
29.0–29.4								1	1	1	4	1	1	1	1			
29.5–29.9							1					4	2	1				
30.0–30.4											3		1	1				
30.5–30.9												1						
31.0–31.4											1	2	1					
31.5–31.9												2						
32.0–32.4								1	1			2		1			2	
32.5–32.9								1			1		2	1	1			
33.0–33.4												3	2				1	
33.5–33.9											1	1	1					

TABLE 1—Continued

Length Frequencies by Age Groups of Lake Tahoe Lake Trout

Fork length class interval (inches)	Number of annuli																	
	0	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII	XIV	XV	XVI	XVII
34.0–34.4												1	2		1			
34.5–34.9													1			1		
35.0–35.4													1	2			1	
35.5–35.9												1						1
36.0–36.4															1	1		
Totals	9	23	13	39	113	377	734	645	426	211	125	81	36	22	7	3	4	1
Mean lengths	2.7	3.9	6.5	10.1	13.8	16.0	17.5	18.9	20.9	22.8	24.5	26.6	28.5	28.1	30.1	33.0	33.3	35.7

Lengths were back calculated to each annulus for individual fish by the following formula (Lagler, 1952):

$$L_i = \frac{S_i(L - a)}{S} + a.$$

Table 2 shows back calculated lengths for each age group. Weighted mean lengths yielded estimates of absolute length attained at the end of any given year of life. Mean annual increments were computed by averaging increments of individual fish. The successive summations of the increments best described growth rates and general growth histories (Figures 2 and 4).

TABLE 2

Calculated Lengths of All Lake Tahoe Lake Trout Collected from 1938 Through 1964

Age group	No. of fish	Mean fork length at capture (inches)	Mean calculated fork length at the end of each year of life (inches)																
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
I	23	3.6	3.5																
II	19	6.6	4.3	6.2															
III	39	10.0	4.3	6.6	8.9														
IV	113	13.8	4.6	7.3	10.1	12.6													
V	377	16.0	4.6	6.2	10.3	12.9	15.0												
VI	734	17.5	4.7	7.2	9.7	12.7	15.0	16.8											
VII	645	18.8	4.6	7.0	9.7	12.3	14.7	16.7	18.3										
VIII	426	20.8	4.7	7.1	9.8	12.5	14.9	17.1	18.9	20.4									
IX	211	22.9	4.7	7.2	10.0	12.7	15.1	17.3	19.2	21.0	22.4								
X	125	24.4	4.7	7.2	10.0	12.5	15.2	17.4	19.5	21.3	22.8	24.1							
XI	81	26.4	4.8	7.3	10.1	13.0	15.7	18.0	20.0	21.8	23.4	24.8	26.1						
XII	36	28.4	4.8	7.4	10.4	13.4	16.3	18.8	20.8	22.8	24.4	25.7	27.2	28.2					
XIII	22	27.9	4.6	7.3	9.7	12.5	15.0	17.0	19.1	20.8	22.4	23.9	25.5	26.7	27.8				
XIV	7	30.0	4.6	7.1	9.7	12.2	14.6	16.6	19.3	20.7	22.5	24.2	25.7	27.0	28.2	29.4			
XV	3	32.9	5.0	7.4	10.1	11.6	14.2	17.1	19.9	22.0	24.0	25.6	27.3	29.1	30.7	31.6	32.5		
XVI	4	33.1	5.0	7.6	10.2	13.2	16.4	19.1	21.4	22.8	24.1	25.9	26.9	28.4	29.8	31.0	32.1	33.1	
XVII	1	35.8	4.3	6.3	8.7	12.2	16.0	18.9	21.2	22.3	23.4	25.3	26.9	28.3	29.5	31.9	33.6	34.7	35.8
Grand mean calculated fork length			4.6	7.0	9.9	12.6	15.0	17.0	18.9	20.9	22.8	24.5	26.3	27.7	28.4	30.4	32.4	33.4	35.8
Increment of mean			4.6	2.4	2.9	2.7	2.4	2.0	1.9	2.0	1.9	1.7	1.8	1.4	0.7	2.0	2.0	1.0	2.4
Mean annual increment*			4.6	2.5	2.8	2.6	2.4	2.0	1.8	1.7	1.5	1.4	1.4	1.2	1.2	1.2	1.0	1.2	1.1
Summation of the mean increments			4.6	7.1	9.9	12.5	14.9	16.9	18.7	20.4	21.9	23.3	24.7	25.9	27.1	28.3	29.3	30.5	31.6
Number of fish 2,866			2,866	2,843	2,824	2,785	2,672	2,295	1,561	916	490	279	154	73	37	15	8	5	1

* Derived from data in Table 4.

Growth histories were calculated separately for males and females collected from 1960 through 1964. The slight differences did not warrant a separate analysis by sex. Other workers reached the same conclusion (Fry, 1949; Rawson, 1961).

Combined data for all years of collection revealed a relatively uniform absolute growth curve and a uniform but slightly decreasing growth rate (Table 2 and Figure 2).

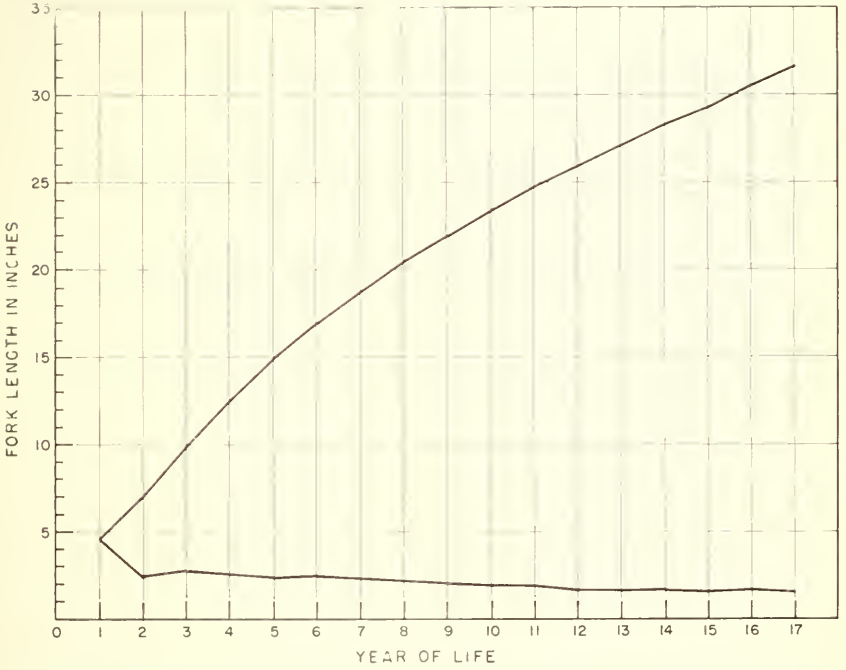

FIGURE 2—Growth of all Lake Tahoe lake trout collected from 1938 through 1964. Upper line shows growth based on the successive summations of the mean increments, and the lower line shows the mean increments of growth.

Growth was analyzed by four major lake areas to explore the possibility of subpopulations as demonstrated by Kennedy (1954) and Rawson (1961). However, no significant differences were detected at Lake Tahoe.

Lee's Phenomenon

Back-calculated lengths from different age groups did not indicate the presence of Lee's Phenomenon (the progressive decrease in calculated lengths when calculated from successively older fish). On the contrary, lengths calculated from older fish tended to be larger (Table 2). This and other information presented later suggests that faster growing fish suffer less mortality than slower growing fish.

Validity of Back Calculations

Back-calculated lengths closely approximated mean lengths at capture for corresponding years of life (Table 2). However, lengths at capture for age groups I and II were smaller than calculated values because

almost half of the fish were collected before annulus formation. These fish were credited with an assumed annulus and assigned to the next higher age group but, as is shown later, they had not completed the year's growth. This occurs in all age groups and tends to lower back-calculated values for the last annulus as well as the lengths at capture.

Cable (1956) and Bulkley (1960) reported the occurrence of a false annulus between the focus and the first annulus in lake trout. It was termed the zero mark. Scales from nine age group 0 and 23 age group I fish were examined to determine if a similar mark occurred in Tahoe. The age group 0 fish, collected from July 16 to December 31, averaged 2.6 inches (range 1.5 to 3.6 inches). Two (1.7 and 1.5 inches) without scales were captured July 20 and August 25 respectively. The others had scales without annuli. There is little doubt that these were true fish of the year.

Ten age group I fish were collected between January 1 and April 30. They averaged 3.0 inches (range 2.5 to 3.8 inches). They had clearly hatched the previous year and must therefore have attained nearly a full year's growth. Although showing no annulus, they were assigned one at the scale edge.

Thirteen age group I fish showing new growth and averaging 4.6 inches (range 3.4 to 5.3 inches) were collected from July 16 to December 31. Their size in relation to date of collection leaves little doubt that they had formed the first annulus the previous winter and had started the next year's growth. Hence, we conclude that Lake Tahoe lake trout scales apparently do not form the zero mark.

Mean back-calculated lengths produced abnormally large annual increments for certain year classes in their later years of life, suggesting either that annuli had been overlooked in older fish, or that faster growing individuals suffered less mortality.

Scales from the 1952 year class (in which the discrepancy was particularly evident) were reexamined for overlooked year marks. We counted all discontinuities in scale sculpturing that might possibly be considered annuli, even if they did not fully meet the criteria. This did not significantly change age designations of fish under age X. Of the 44 fish 10 years or older, 16 may have been incorrectly aged. However, calculated lengths based on these new scale readings were still greater at all ages than for most other year classes, suggesting that the 1952 year class did indeed grow more rapidly. Moreover, the new calculated lengths of older fish remained, on the average, slightly larger than those calculated from younger ones. This not only increased confidence in our age determinations, but also indicated higher survival of faster growing fish.

Miller and Kennedy (1948) suggested this sort of differential mortality in Great Bear Lake lake trout. Martin (1966) reported a similar situation in Algonquin Park lakes: "Plankton-feeding lake trout grow more slowly, do not reach as great a size or age as fish-feeders, and mature at a smaller size and younger age. Trout transferred from a plankton-feeding to a fish-feeding population grow at a faster rate and extend their life-span." McCart (1965) coupled slow growth with high mortalities in the pygmy whitefish (*Prosopium coulteri*).

FLUCTUATIONS IN GROWTH

Calendar Year Growth

Deviations from the mean annual growth increment for the period 1940 through 1962 were calculated for each calendar year by Hile's method (1941).

The general pattern for the 22-year period is one of gradually decreasing growth (Table 3 and Figure 3). Growth was better than aver-

TABLE 3

Percentage Deviation from the Mean Annual Growth Increment of Lake Tahoe Lake Trout *

Percentage deviation from mean annual growth in calendar years											
1940	1941	1942	1943	1944	1945	1946	1947	1948	1949	1950	1951
+6.8	+7.1	+8.1	+4.7	+7.1	+6.5	+5.0	+1.3	−1.1	−1.7	−2.7	−0.6
(1)	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(6)	(6)	(7)
1952	1953	1954	1955	1956	1957	1958	1959	1960	1961	1962	
−0.1	−0.2	−1.6	−0.1	+1.6	0.0	+0.8	−1.5	−9.8	−8.3	−3.1	
(8)	(9)	(10)	(11)	(9)	(9)	(10)	(11)	(12)	(13)	(13)	

* First-year growth included with a minimum five fish sample size. Number of years in parentheses.

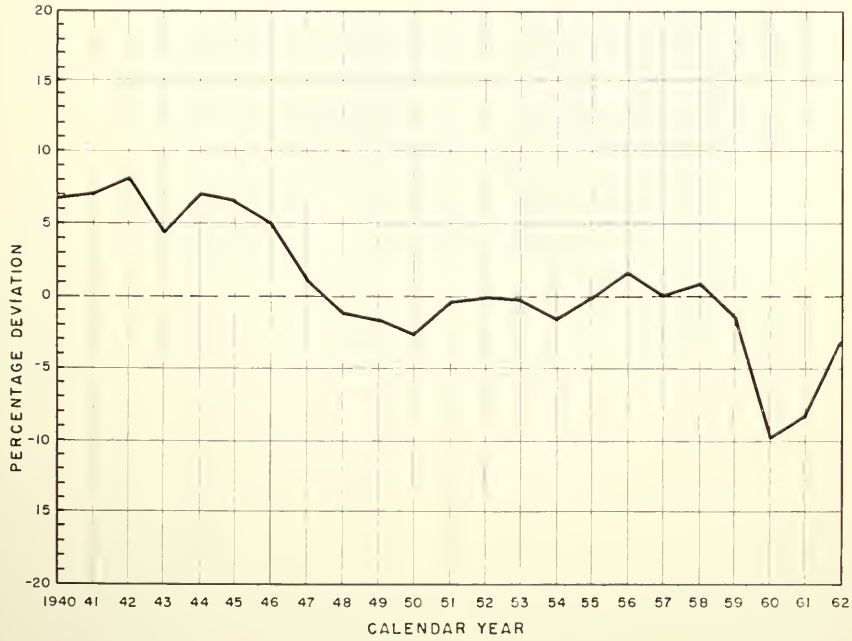

FIGURE 3—Percentage deviation from the mean annual growth increment of Lake Tahae lake trout.

age from 1940 through 1946 and reached a high of 8.1% above average in 1942. Growth remained close to average from 1947 through 1959, and reached a low of 9.8% below average in 1960.

Year-Class Growth

Generally, growth was quite uniform for all year classes. However, the 1940, 1943, and 1952 year classes were larger than all others at most ages (Table 4 and Figure 4). Also, there was a downward trend in size from the 1958 through 1963 classes. Growth was extremely constant for one-year-old fish and became only slightly more irregular with increasing age. The 1944 through 1951 year classes showed very similar growth for all ages.

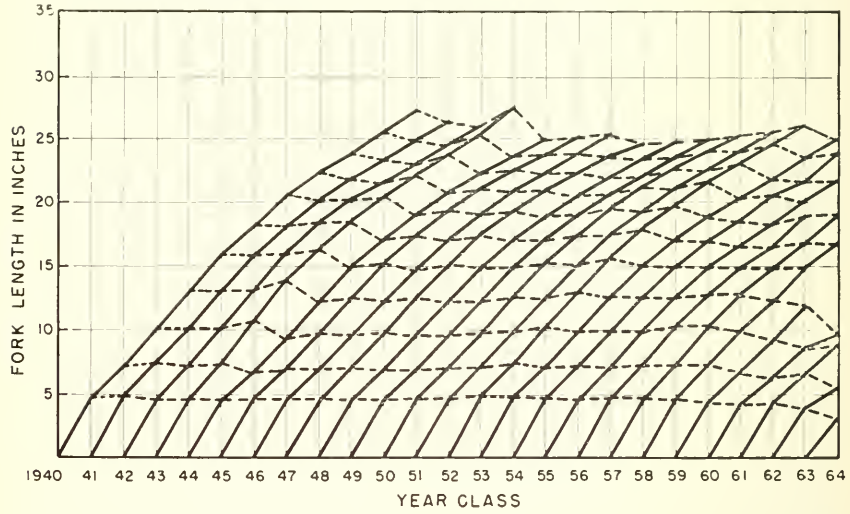

FIGURE 4—Growth histories of the different year classes of Lake Tahoe lake trout (based on successive summations of the mean increments). Lengths at corresponding years of life are connected by dotted lines. Year classes before 1940 and calculated lengths over 11 years omitted.

TABLE 4

Length at the End of Each Year of Life for Lake Tahoe Lake Trout by Year Class (Number of Fish in Parentheses)

Year	Mean fork length at the end of each year of life* (inches)																
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1924	4.4	6.6	8.8	10.7	13.3	14.4	15.8	18.3	20.1	21.5	22.6	23.5	24.3	25.0			
	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)			
1927	4.5	6.0	8.5	10.5	12.8	15.1	16.9	18.8	20.7	22.2	23.8						
	(4)	(4)	(4)	(4)	(4)	(4)	(4)	(4)	(4)	(4)	(4)						
1928	4.5	6.9	8.9	11.6	14.3	17.0	18.6	20.6	22.1	23.4	21.6						
	(4)	(4)	(4)	(4)	(4)	(4)	(4)	(4)	(4)	(4)	(1)						
1929	4.5	6.4	8.8	11.4	13.9	15.4	17.9	19.6	20.8	22.4							
	(13)	(13)	(13)	(13)	(13)	(13)	(13)	(13)	(13)	(5)							
1930	4.6	6.6	9.1	11.7	14.1	16.3	18.2	19.9	21.4								
	(34)	(31)	(34)	(34)	(34)	(34)	(34)	(34)	(14)								
1931	4.5	6.6	9.1	11.4	13.8	15.9	17.6	19.4									
	(44)	(44)	(44)	(44)	(44)	(44)	(44)	(19)									
1932	4.7	7.1	9.8	12.4	14.8	16.9	18.8										
	(21)	(21)	(21)	(21)	(21)	(21)	(8)										
1933	4.4	6.9	10.3	12.7	15.1	17.0											
	(11)	(11)	(11)	(11)	(11)	(9)											
1934	4.7	7.4	10.3	12.8	14.4												
	(3)	(3)	(3)	(3)	(2)												
1936	4.3	7.2	10.2	12.5	15.4	17.6	19.6	21.4	22.9	23.8	25.2	26.1	27.3				
	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)				
1937	4.0	5.6	8.4	11.8	15.1	18.0	20.4	22.1	23.4	24.2	25.1	25.7					
	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)					
1938	4.8	7.6	10.1	13.2	15.7	18.1	20.4	22.1	23.8	25.3	26.4						
	(9)	(9)	(9)	(9)	(9)	(9)	(9)	(9)	(9)	(9)	(9)						
1939	4.6	6.5	9.6	12.5	14.8	17.1	19.8	21.6	23.1	24.6							
	(8)	(8)	(8)	(8)	(8)	(8)	(8)	(8)	(8)	(8)							
1940	4.7	7.1	10.0	13.0	15.8	18.1	20.5	22.3	23.7	25.5	27.2	28.6	29.7	32.1	33.5	34.9	36.0
	(23)	(23)	(23)	(23)	(23)	(23)	(23)	(23)	(23)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)
1941	4.8	7.5	10.1	13.0	15.7	18.1	20.1	21.8	23.3	24.8	26.2	27.6	29.0	30.1			
	(39)	(39)	(39)	(39)	(39)	(39)	(39)	(39)	(1)	(1)	(1)	(1)	(1)	(1)			
1942	4.6	7.2	10.1	13.1	15.9	18.4	20.2	21.5	23.0	24.5	25.9	27.0	28.2	29.4			
	(24)	(24)	(24)	(24)	(24)	(24)	(24)	(2)	(2)	(2)	(2)	(2)	(2)	(1)			
1943	4.6	7.4	10.7	13.9	16.3	18.5	20.4	22.1	23.8	25.3	27.4	28.3	29.6	30.7			
	(18)	(18)	(18)	(18)	(18)	(18)	(4)	(4)	(4)	(4)	(4)	(4)	(3)	(1)			
1944	4.5	6.7	9.3	12.2	14.9	17.1	19.0	20.8	22.3	23.6	24.9	26.0					
	(19)	(19)	(19)	(19)	(19)	(13)	(13)	(13)	(13)	(13)	(13)	(4)					
1945	4.6	6.9	9.7	12.5	15.2	17.4	19.4	21.0	22.5	23.7	25.1	26.4	27.9	28.9	29.8	30.8	
	(25)	(25)	(25)	(25)	(22)	(22)	(22)	(22)	(22)	(22)	(7)	(3)	(3)	(3)	(3)	(3)	
1946	4.6	6.9	9.6	12.2	14.7	17.0	19.0	20.8	22.2	23.7	25.3	26.7	28.0	28.8	29.7		
	(34)	(34)	(31)	(34)	(34)	(34)	(34)	(34)	(34)	(13)	(3)	(1)	(1)	(1)	(1)		
1947	4.6	7.0	9.8	12.5	15.1	17.4	19.3	20.9	22.4	23.6	24.6						
	(54)	(54)	(54)	(54)	(54)	(54)	(54)	(54)	(12)	(3)	(2)						
1948	4.6	6.9	9.6	12.2	14.8	17.0	18.9	20.5	22.0	23.4	24.7	26.1	27.3	28.5	29.7	31.2	
	(94)	(94)	(94)	(94)	(94)	(94)	(94)	(39)	(20)	(16)	(11)	(11)	(10)	(4)	(4)	(1)	
1949	4.5	6.8	9.5	12.2	14.8	17.1	19.0	20.7	22.0	23.5	24.9	26.0	27.1	28.1	29.1		
	(79)	(79)	(79)	(79)	(79)	(79)	(49)	(26)	(17)	(14)	(14)	(14)	(6)	(1)	(1)		
1950	4.6	7.0	9.7	12.6	15.2	17.4	19.5	21.2	22.7	24.0	25.3	26.6	27.8	29.3			
	(77)	(77)	(77)	(77)	(77)	(72)	(59)	(46)	(39)	(39)	(37)	(14)	(6)	(1)			
1951	4.6	7.1	9.8	12.5	15.1	17.5	19.3	21.1	22.6	24.0	25.5	26.7	28.7				
	(80)	(80)	(80)	(80)	(79)	(75)	(70)	(57)	(57)	(54)	(24)	(8)	(1)				
1952	4.8	7.3	10.2	13.0	15.6	17.9	19.8	21.7	23.1	24.6	26.2	27.7					
	(125)	(125)	(125)	(125)	(125)	(121)	(109)	(109)	(104)	(44)	(12)	(5)					
1953	4.7	7.1	9.9	12.6	15.0	17.1	18.9	20.4	21.9	23.6	25.0						
	(208)	(208)	(208)	(208)	(208)	(207)	(207)	(187)	(67)	(17)	(4)						
1954	4.7	7.2	9.9	12.6	15.0	17.0	18.6	20.6	21.7	24.0							
	(357)	(357)	(357)	(356)	(356)	(356)	(333)	(132)	(17)	(1)							
1955	4.6	7.1	9.9	12.6	14.6	16.7	18.4	20.2	21.7								
	(545)	(545)	(545)	(545)	(545)	(524)	(250)	(33)	(1)								
1956	4.7	7.3	10.3	12.8	14.9	16.6	18.5										
	(438)	(438)	(438)	(438)	(432)	(304)	(44)										
1957	4.6	7.3	10.3	12.8	14.9	16.9	18.7										
	(267)	(267)	(267)	(267)	(236)	(83)	(4)										
1958	4.6	7.3	10.0	12.4	15.0	16.9											
	(101)	(101)	(101)	(99)	(53)	(2)											
1959	4.4	6.7	9.4	12.1													
	(39)	(39)	(38)	(24)													
1960	4.3	6.4	8.7	9.7													
	(24)	(24)	(22)	(1)													
1961	4.4	6.7	9.0														
	(7)	(5)	(1)														
1962	4.0	5.6															
	(18)	(12)															
1963	3.3																
	(15)																

TABLE 4—Continued

Length at the End of Each Year of Life for Lake Tahoe Lake Trout by Year Class

Year	Mean fork length at the end of each year of life* (inches)																
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Summation of the mean increments	4.6	7.1	9.9	12.5	14.9	16.9	18.7	20.4	21.9	23.3	24.7	25.9	27.1	28.3	29.3	30.5	31.6
Mean increment	4.6	2.5	2.8	2.6	2.4	2.0	1.8	1.7	1.5	1.4	1.4	1.2	1.2	1.2	1.0	1.2	1.1
Number of fish	2,866	2,843	2,824	2,785	2,672	2,295	1,561	916	490	279	154	73	37	15	8	5	1

*Lengths are based on the summations of the mean increments.

To compare growth before 1940, when samples were small and scattered, we divided the 40-year period for which we had data into four parts: 1924 through 1933 (10 years), 1934 through 1944 (11 years), 1945 through 1954 (10 years), 1955 through 1963 (9 years) (Table 5). Growth tended to be slowest during the first period and fastest during the second (Figure 5). Growth in the latter two periods (1945 through 1954 and 1955 through 1963) was intermediate, with 1945 through 1954 year classes showing slightly but consistently better growth.

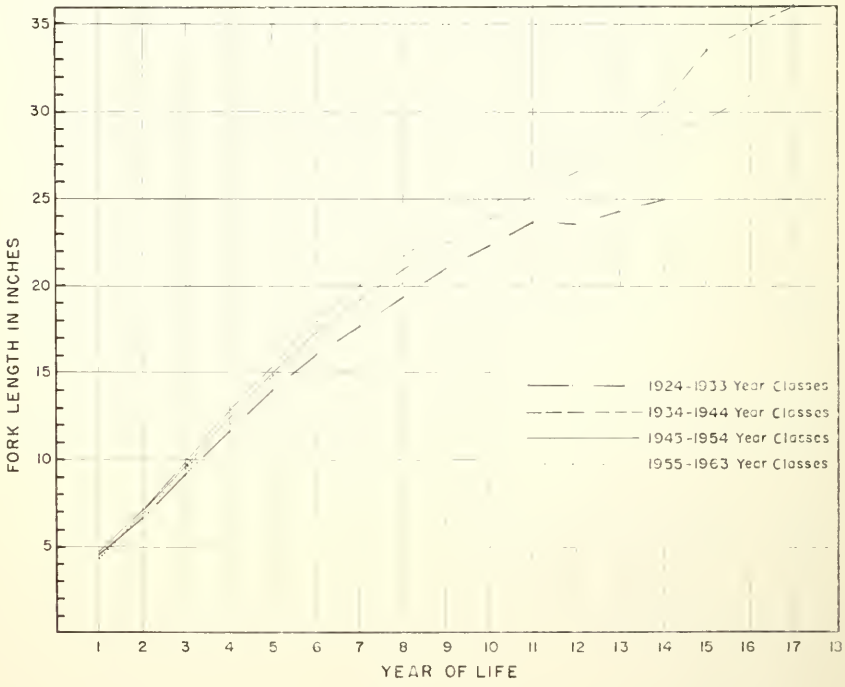

FIGURE 5—Growth histories of Lake Tahoe lake trout, grouped by year classes.

TABLE 5

Mean Lengths of Lake Tahoe Lake Trout Grouped by Year Classes (Number of Year Classes in Parentheses)

Year classes	Mean fork length at the end of each year of life (inches)																
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1921 1933	4.5 (8)	6.6 (8)	9.2 (8)	11.6 (8)	14.0 (8)	16.0 (8)	17.7 (7)	19.4 (6)	21.0 (5)	22.4 (4)	23.7 (3)	23.5 (1)	24.3 (1)	25.0 (1)			
1934-1944	4.6 (10)	7.0 (10)	9.9 (10)	12.8 (10)	15.4 (10)	17.9 (9)	20.0 (9)	21.7 (9)	23.3 (9)	24.6 (9)	26.0 (8)	27.0 (7)	28.8 (5)	30.6 (4)	33.5 (1)	34.9 (1)	36.0 (1)
1945-1954	4.6 (10)	7.0 (10)	9.8 (10)	12.5 (10)	15.0 (10)	17.3 (10)	19.2 (10)	20.9 (10)	22.3 (10)	23.8 (10)	25.2 (9)	26.6 (7)	27.8 (6)	28.7 (5)	29.6 (4)	31.0 (2)	
1955-1963	4.3 (9)	6.8 (8)	9.7 (7)	12.1 (6)	14.9 (4)	16.8 (4)	18.5 (3)	20.2 (1)	21.7 (1)								

In general, growth rates increased from a relatively low level in the late 1920's and early 1930's to a 40-year high in the 1940's. From 1947 through 1959 they were relatively constant at an intermediate level. They have since been lower, but the period is too short to predict the impact on the ultimate growth of year classes concerned.

Thus, definite changes in growth have occurred during the 40-year history of lake trout growth in Tahoe. However, they have tended to be small and cyclic in nature. There is no information available on the possible causes of these fluctuations.

SEASONAL GROWTH

Time of Annulus Formation

The percentage of fish showing a new annulus on their scales was determined for semimonthly intervals (Table 6 and Figure 6). The annulus is not recognizable until there has been some new growth, so the annulus actually forms somewhat earlier.

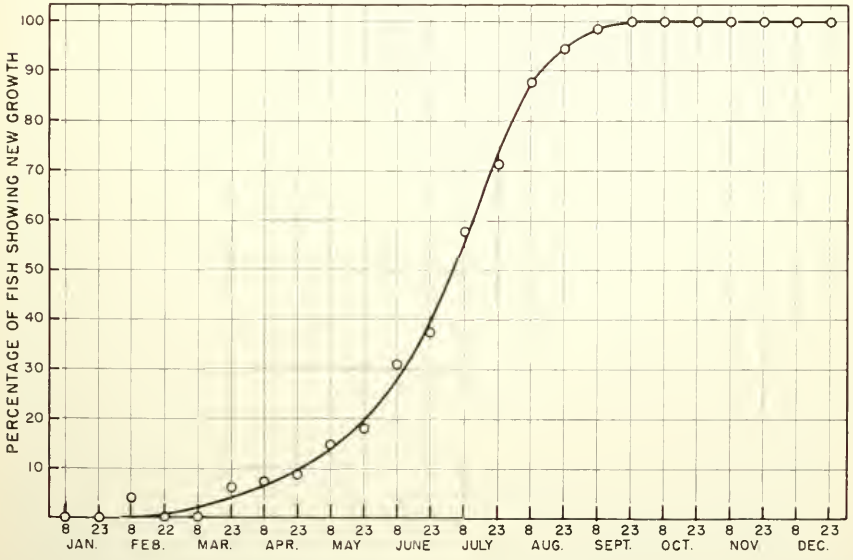
PERCENTAGE OF FISH SHOWING NEW GROWTH
100
90
80
70
60
50
40
30
20
10
8 23 8 22 8 23 8 23 8 23 8 23 8 23 8 23 8 23 8 23 8 23 8 23
JAN. FEB. MAR. APR. MAY JUNE JULY AUG. SEPT. OCT. NOV. DEC.

FIGURE 6—Percentage of Lake Tahoe lake trout showing new growth; for all years and all ages combined. Curve drawn by inspection.

TABLE 6

Percentage of Lake Tahoe Lake Trout Showing New Growth, by Semimonthly Intervals

Date	Number without new growth	Number with new growth	Percentage with new growth	Date	Number without new growth	Number with new growth	Percentage with new growth
Jan. 1-15	75	0	0.0	July 1-15	68	95	58.3
16-31	43	0	0.0	16-31	27	96	78.0
Feb. 1-15	53	2	3.6	Aug. 1-15	16	116	87.9
16-29	37	0	0.0	16-31	4	74	94.9
Mar. 1-15	43	0	0.0	Sept. 1-15	2	155	98.3
16-31	145	9	5.8	16-30	0	102	100.0
Apr. 1-15	144	10	6.5	Oct. 1-15	0	90	100.0
16-30	118	11	8.5	16-31	0	99	100.0
May 1-15	80	14	14.9	Nov. 1-15	0	100	100.0
16-31	204	45	18.1	16-30	0	91	100.0
June 1-15	204	90	30.6	Dec. 1-15	0	102	100.0
16-30	108	74	40.7	16-31	0	120	100.0

New annuli were observed on two fish captured during the first half of February. However, they were not found again until the latter half of March. Subsequently the percentage with new annuli increased steadily to 100% in the latter half of September. Thereafter, all fish exhibited new annuli. Cable (1956) reported a similar pattern in Lake Michigan fish.

Seasonal Progression of Growth

The progression of seasonal growth was calculated by Hile's method (1941). Tahoe lake trout appeared to grow throughout the year. Growth was fastest from mid-June to late September, paralleling the situation in Great Slave Lake (Kennedy, 1954), Lake Michigan (Cable, 1956) and Lake Superior (Lawrie, 1963).

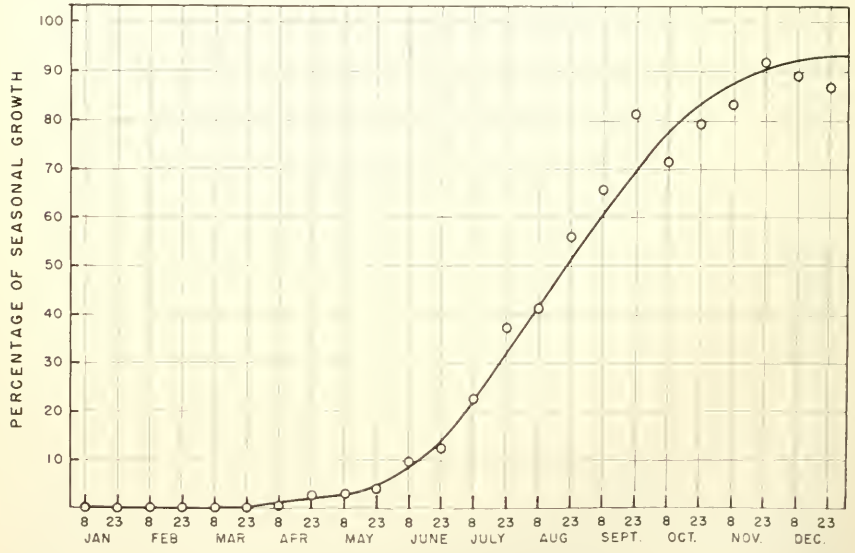

FIGURE 7—Percentage of seasonal growth of Lake Tahoe lake trout; for all years and all ages combined. Curve drawn by inspection.

Growth was insignificant until late March, when an average of 1.4% of the expected annual growth was completed. Subsequently, this figure gradually increased, reaching 50% in late August (Figure 7). By December, it had reached about 93%, leaving approximately 7% to occur from January 1 to the time of annulus formation.

The percentage of annual growth attained at any given time varied with age, with no consistent relationship apparent. However, the general pattern was essentially the same each year.

LENGTH-WEIGHT RELATIONSHIP

The length-weight relationship was calculated for 2,416 lake trout collected from 1961 through 1964. Fish were combined without regard to sex, state of maturity, method of collection, or time of collection. They were weighed to the nearest 0.01 pound.

The length-weight relationship is best described by the equation $\log W = -3.63591 + 3.17941 \log L$, or $W = 0.0043242\ L^{3.17941}$ (Figure 8), where W is weight in pounds and hundredths and L is fork length in inches and tenths.

Empirical weights averaged for 0.5-inch length intervals compared closely with calculated lengths (Table 7).

TABLE 7

Calculated and Empirical Weights and Condition Factors for Lake Tahoe Lake Trout

	Weight (pounds)			Condition factor			Weight (pounds)			Condition factor	
Fork length*	No. fish	Calculated	Empirical	No. fish	Condition factor	Fork length*	No. fish	Calculated	Empirical	No. fish	Condition factor
3.0	3	0.01	0.01	2	32.2	20.5	79	3.43	3.50	88	40.1
3.5	1	0.01	0.01	0	--	21.0	78	3.70	3.77	75	41.0
4.0	0	0.02	--	0	--	21.5	47	3.99	4.16	48	41.3
4.5	2	0.03	0.04	4	34.0	22.0	58	4.29	4.29	56	40.8
5.0	4	0.04	0.04	4	31.6	22.5	42	4.61	4.78	45	42.2
5.5	1	0.05	0.05	1	32.2	23.0	56	4.94	5.00	55	41.6
6.0	2	0.07	0.07	2	31.4	23.5	32	5.29	5.42	32	42.5
6.5	1	0.09	0.11	1	35.6	24.0	27	5.65	6.06	26	43.9
7.0	2	0.11	0.12	2	32.2	24.5	28	6.04	6.39	29	43.1
7.5	3	0.14	0.15	4	36.8	25.0	22	6.44	6.75	21	42.8
8.0	1	0.17	0.16	1	33.7	25.5	14	6.86	7.14	16	44.3
8.5	5	0.21	0.23	8	35.6	26.0	11	7.29	7.81	13	45.8
9.0	2	0.25	0.29	2	32.6	26.5	12	7.75	8.18	11	45.1
9.5	11	0.30	0.33	14	37.2	27.0	9	8.22	9.57	11	48.0
10.0	13	0.35	0.36	12	37.1	27.5	10	8.72	9.64	11	45.9
10.5	6	0.41	0.44	6	38.0	28.0	3	9.23	9.83	3	45.4
11.0	8	0.47	0.47	10	36.1	28.5	6	9.76	10.00	6	43.6
11.5	10	0.55	0.56	14	35.9	29.0	4	10.32	10.86	4	44.8
12.0	16	0.62	0.63	17	36.6	29.5	7	10.90	12.70	9	48.9
12.5	18	0.71	0.72	17	36.4	30.0	2	11.49	13.35	2	49.2
13.0	18	0.80	0.81	20	36.6	30.5	2	12.11	14.05	2	49.2
13.5	34	0.91	0.90	37	38.0	31.0	2	12.76	14.55	2	48.3
14.0	36	1.02	1.03	43	37.1	31.5	1	13.42	16.10	1	31.5
14.5	72	1.14	1.16	74	37.9	32.0	3	14.11	13.95	3	40.8
15.0	81	1.27	1.28	86	37.8	32.5	4	14.82	15.31	4	44.2
15.5	120	1.41	1.40	117	38.2	33.0	4	15.56	17.25	3	47.9
16.0	134	1.56	1.55	136	38.6	33.5	2	16.32	17.75	2	47.0
16.5	154	1.72	1.72	160	37.7	34.0	0	17.11	--	0	--
17.0	193	1.89	1.82	208	38.8	34.5	1	17.92	19.10	1	46.9
17.5	207	2.07	2.05	214	38.2						
18.0	189	2.27	2.23	200	37.1						
18.5	143	2.47	2.41	149	38.3						
19.0	156	2.69	2.65	152	38.8						
19.5	114	2.92	2.92	115	39.6						
20.0	90	3.17	3.26	97	41.0						

* Midpoint of 0.5-inch intervals.

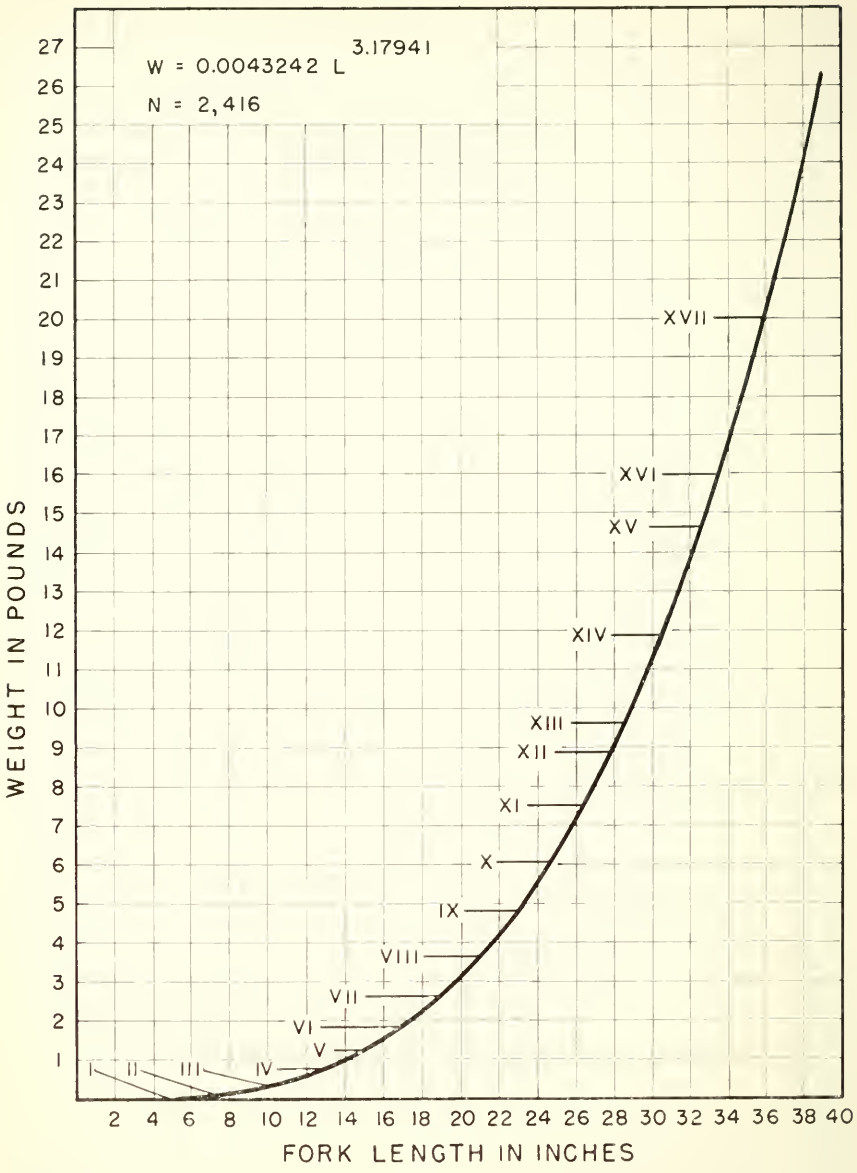

FIGURE 8—Length, weight, and age relationship of Lake Tahoe lake trout. Line fitted by the least squares method.

CONDITION FACTOR

Condition factors (C) were calculated for 2 509 lake trout collected from 1961 through 1964 by the formula $C = \frac{W10^5}{L^3}$, where W is weight in hundredths of pounds and L is fork length in tenths of inches.

Condition factors for individual fish were grouped by 0.5-inch length intervals and averaged (Table 8). Condition factors tended to increase with size.

To assess seasonal changes in condition, specimens in the 15.0- to 19.9-inch length interval were combined and their average monthly condition factors calculated (Figure 9). This group was selected to reduce variability caused by size and state of maturity and because their numbers permitted monthly comparisons.

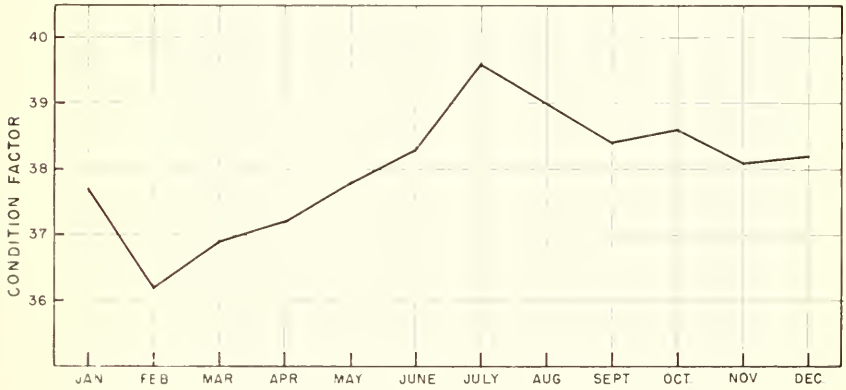

FIGURE 9—Monthly condition factors for Lake Tahoe lake trout between 15.0 and 19.9 inches.

There was an increase in the relative robustness beginning in March and continuing until July, and a decrease extending throughout the fall and winter months.

FORK LENGTH—TOTAL LENGTH RELATIONSHIP

A single straight-line regression was calculated by least squares to describe the fork length—total length relationship for Lake Tahoe lake trout. The equation is $Y = 0.0914 + 1.0959X$, where Y is total length in inches and X is fork length in inches. Data indicated that the same regression can be used for all size groups.

DISCUSSION

Lake Tahoe anglers with many years of experience uniformly complain that lake trout are smaller now than in previous years. They generally attribute this change to a reduction in the cyprinid population. However, if the highly piscivorous lake trout had depleted its forage supply, this should be reflected in reduced growth rates. No such decline is apparent during the past 40 years. In fact, growth has been relatively constant, with only minor fluctuations.

Comparisons With Other Lakes

Lake Tahoe lake trout grow relatively slowly in comparison with populations in other large, deep, oligotrophic lakes (Table 8 and Figure 10). Only in 3 of 10 lakes selected (Lake Superior, Lake Michigan, and Great Bear Lake) do lake trout grow more slowly than in Lake Tahoe.

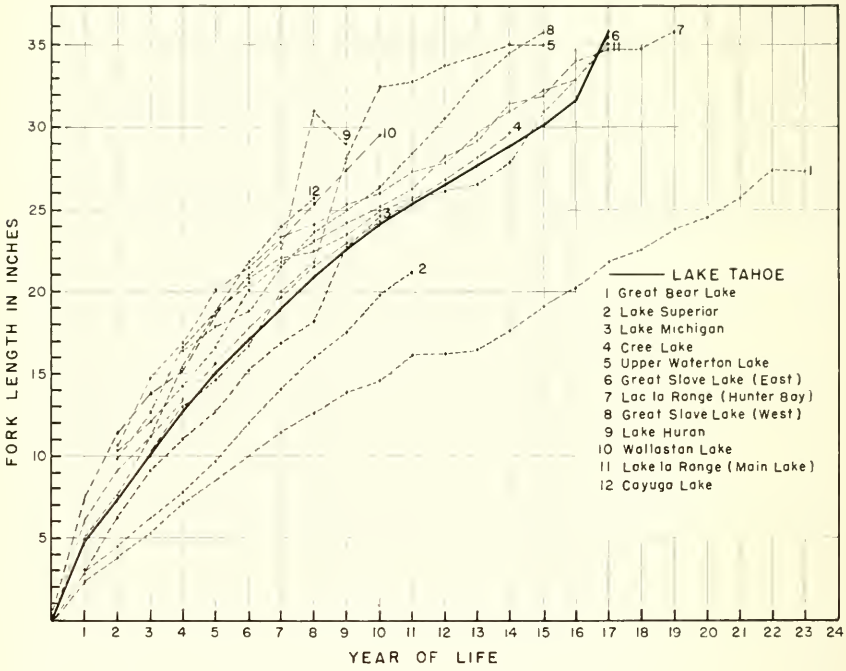

FIGURE 10—Growth of Lake Tahoe lake trout compared with growth of lake trout from other oligotrophic lakes.

Inadequate transitional forage between plankton and fish, coupled with poor supplies of summer forage, may be responsible for the slow growth in Lake Tahoe.

The seasonal availability of forage is reflected in the monthly condition factors (Figure 9). Lake trout begin to range into shallower water in early spring and feed heavily there until late June (Lake Tahoe Fisheries Study, unpublished data). Accordingly, condition factors improve throughout the spring and early summer. During most of the summer, however, lake trout occupy depths below 100 feet, while its principal forage fishes (tui chub, *Siphateles bicolor*; Lahontan redside, *Richardsonius egregius*; and the Tahoe sucker, *Catostomus tahoensis*) and the crayfish (*Pacifastacus leniusculus*) are concentrated in shallow water. However, its most important forage fish (*Cottus beldingii*) is abundant down to 100 feet, with lesser numbers down to 300 feet. Significantly, sculpin and plankton are the primary foods of lake trout in the summer. The unavailability of abundant summer forage produces a gradual decline in condition in midsummer and fall.

TABLE 8

Growth of Lake Trout in Some Large Oligotrophic Lakes

Name of lake[1]	Fork length for each year of life (inches)																					
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
Great Bear Lake[4] (Miller and Kennedy, 1948)	2.5	3.9	5.3	7.1	--	--	11.5	12.6	13.9	14.6	16.2	16.2	16.5	17.7	19.2	20.3	21.9	22.6	23.9	24.6	25.8	27.6
Lake Superior[6] (Rahrer, 1965)	3.1	4.6	6.2	7.7	9.7	12.0	14.1	16.0	17.6	19.8	21.1											
Lake Michigan[6] (Van Oosten and Eschmeyer, 1956)	3.0	6.4	9.1	11.0	12.7	15.2	16.9	18.2	22.7	21.6												
Lake Tahoe[2] (Present study)	**4.6**	**7.1**	**9.9**	**12.6**	**15.0**	**17.0**	**18.9**	**20.8**	**22.5**	**24.0**	**25.3**	**26.5**	**27.7**	**28.9**	**30.1**	**31.7**	**36.0**					
Cree Lake[3] (Rawson, 1959)	6.0	9.0	11.1	13.5	15.6	17.8	19.7	21.6	23.0	24.2	25.4	26.8	28.2	29.7								
Upper Waterton Lake[3] (Cuerrier and Schultz, 1957)	--	--	9.9	12.9	14.6	16.7	20.0	21.8	28.1	32.5	32.8	33.8	-	35.0	35.0	36.5						
Great Slave Lake (East)[5] (Kennedy, 1954)	--	--	--	16.4	17.9	18.8	21.6	23.7	25.0	26.3	28.4	30.6	32.9	34.5	35.7	37.1	37.3	38.5	39.6	39.1	--	41.5
Lac la Ronge (Hunter Bay)[3] (Rawson, 1961)	--	10.7	12.2	14.2	16.6	20.1	21.8	23.1	24.2	25.2	26.2	28.3	29.2	31.4	31.9	33.9	34.7	34.7	35.7	37.0	38.1	40.4
Great Slave Lake (West)[5] (Kennedy, 1954)	--	--	--	--	--	20.7	22.1	22.5	23.5	24.9	25.5	26.2	26.6	30.8	32.8	35.1	37.5	34.8	34.4	33.7	41.3	36.7
Lake Huron[3] (Fry, 1953)	--	10.0	12.7	16.5	18.8	20.6	22.7	31.0	29.0													
Wollaston Lake[3] (Rawson, 1959)	7.5	11.3	13.7	15.1	18.5	20.9	23.1	25.3	27.4	29.5												
Lac la Ronge (Main Lake)[3] (Rawson, 1961)	--	10.5	14.8	16.8	20.1	23.4	23.2	24.1	25.3	25.0	27.3	27.9										
Cayuga Lake[2] (Webster et al., 1960)	4.8	7.6	11.1	15.2	18.8	21.8	24.0	25.6														

[1] Lakes are ranked by increasing size of lake trout at age 7.
[2] Calculated fork length in inches.
[3] Empirical fork length in inches.
[4] Converted from epmirical fork length in centimeters to inches.
[5] Converted from weight in pounds to fork length in inches.
[6] Converted from total length in inches to fork length in inches.

Two new forage organisms, the opossum shrimp (*Mysis relicta*) and Bonneville cisco (*Prosopium gemmiferum*), have been introduced into Lake Tahoe to improve the summer food supply for lake trout and possibly other game species (Linn and Frantz, 1965; Frantz and Cordone, 1965). Their establishment should result in improved growth and condition of the lake trout (Martin, 1966).

Comparing growth of lake trout from various areas in eastern United States and Canada, Rawson (1961) and Martin (1952) noted the pattern of relatively fast growth in more southerly lakes and slow growth in the far north. Despite Tahoe's southern location, growth of lake trout is very slow. This is not surprising, however, in view of the extreme oligotrophic character of Lake Tahoe.

SUMMARY

The growth of lake trout from Lake Tahoe, based on scales collected from 1938 through 1964, was studied. Average lengths for ages 1 through 17 were: 4.6, 7.0, 9.9, 12.6, 15.0, 17.0, 18.9 20.9, 22.8, 24.5, 26.3, 27.7, 28.4, 30.4, 32.4, 33.4, and 35.8 inches FL, respectively.

Growth has been relatively constant for the past 40 years, with only minor fluctuations. Growth of the 1940, 1943, and 1952 year classes exceeded that of other year classes at most ages.

Data suggest that faster growing fish suffer relatively lower mortalities.

Annuli formed from early February to mid-September. Growth was most rapid between mid-June and late September.

The weight-length relationship is $W = -3.63591 + 3.17941 \log L$. Robustness increased with size. Fish from 15.0- to 19.9-inches FL increased in robustness in the spring and early summer, and then decreased throughout the fall and winter.

The fork length — total length formula is $Y = 0.0914 + 1.0959X$.

Lake trout grew more slowly in Lake Tahoe than in all but 3 of 10 other large oligotrophic lakes.

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MARINE SPORTFISHING SURVEY OF SOUTHERN CALIFORNIA PIERS AND JETTIES, 1963[1]

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In 1962 the California Department of Fish and Game initiated a project to ascertain the magnitude and significance of sportfishing activities from piers, jetties, the shore line, and private vessels in southern California marine waters. The first of this three-phase program was a creel census of sport fishermen on piers and jetties during the calendar year 1963. The census incorporated a probability sampling plan designed to yield estimates of total effort, total numbers of fish caught, and species composition of the catch.

We estimate that a minimum of 5.1 million man-hours of fishing was expended in catching 1.86 million fish from southern California marine piers and jetties during the period February through December 1963. Slightly over half of this effort and catch, 54.4 and 50.7%, was expended from May through August. The catch was comprised of 49 species of fishes belonging to 26 family groups, the most significant being croakers, surfperches, and bonito. Well over 60% of the total activity and catch occurred from piers.

We recommend: (i) that the California Wildlife Conservation Board continue its capital outlay program for pier development; (ii) that periodic surveys be undertaken to assess sportfishing activities from piers, jetties, the shore line, and private boats along the entire California coast; (iii) that life history investigations be initiated for the five most important species of fishes to southern California pier and jetty fishermen; namely, queenfish, white croaker, walleye surfperch, Pacific bonito, and shiner perch.

INTRODUCTION

The California Department of Fish and Game's marine biological investigations have centered on faunal identification, on life history research, on the collection of fishery data, and, on a few selected species (i.e. sardines, mackerel, and barracuda), analysis of population dynamics. Limited finances have, until recently, restricted most of these efforts to the more desirable and popular animal species and to the fishing industries (commercial and sport) which exploit them. Specifically, the Department has collected detailed commercial fishing information since 1916 and data of the sportfishing partyboat fleet since 1936. Sport fishing from piers, jetties, the shore line, and private boats has not been measured or documented, except for a limited survey of surf fishermen (utilizing a voluntary catch record system) between 1952 and 1956 (Carlisle, Schott, and Abramson, 1960).

In 1958, the Department initiated its first large-scale investigation aimed at measuring marine sportfishing activities from piers jetties, the shore line, and private boats. Because of limited funds, the study, a

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[2] Now with Maine Department of Sea and Shore Fisheries.
[3] Now with Inland Fisheries Branch, California Department of Fish and Game.

Federal Aid project, was restricted to central and northern California (Miller and Gotshall, 1965).

Manpower and funds became available in 1962 for a similar survey of southern California. The general purpose of this project was to ascertain the magnitude and significance of sportfishing activities from piers, jetties, the shore line, and private vessels in the marine waters between Point Conception and the United States-Mexican boundary.

Monetary and staffing limitations restricted the scope and extent of the program. Thus, the first phase of our investigation, conducted during the calendar year 1963, encompassed only piers and jetties extending out into the open sea. Surveys of private vessels and the shore line were scheduled for 1964 and 1965, respectively.

A limited budget influenced the final design of our survey because it only permitted calculating estimates (with confidence intervals) of total effort, total numbers of fish caught, and species composition of catch for groups of structures (i.e., 22 piers and 18 jetties, and the San Pedro breakwater). The cost of obtaining similar estimates for each individual structure would have exceeded the available budget several times over.

PRELIMINARY SURVEY

A reconnaissance of southern California marine sportfishing facilities, exclusive of partyboat operations, was undertaken in 1962 to aid in developing a creel census plan applicable to our area. All piers, jetties, harbors, and many of the accessible shore line areas between Point Conception and the United States-Mexican boundary were visited during the summer and fall. Each distinct unit was described by noting its location, ownership, hours available to the public, fishing activities, proximity of bait and tackle shops, boat launching equipment, skiff rental, tram services, etc.

For this study, piers were defined as man-made structures extending into the ocean, supported above the water by pilings, and either paved or planked to allow pedestrian or vehicular traffic or both. Jetties were defined as man-made structures extending fingerlike into the ocean, with a relatively solid mass under water and a craggy, uneven profile above it. These distinctions were necessary because fishermen using piers have different activity patterns than those using jetties. The differences are primarily physical, since it is much easier to walk or ride to the end of a pier than to scramble over the uneven, rocky, and sometimes slippery surface of a jetty. Also, bait and tackle shops, refreshment stands, comfort stations, and provisions for cleaning fish are in close association with many piers. Finally, it appeared reasonable to assume that the catch would differ significantly between the two types of structures.

Our preliminary survey revealed 37 piers (piling type), 42 jetties (mostly constructed of rock), and 9 harbors with approximately 120 boating facilities (launching ramps, mechanical hoists, and organized docking units) in the survey area. Many private facilities were not open to the general public. Others were for industrial or military use only, and some were unsafe or condemned.

DEVELOPMENT OF A SAMPLING TECHNIQUE

We decided to develop first a censusing technique for piers and jetties because of their seeming extensive fishing use and easy accessibility. Thus, two of the busiest structures, Belmont Shore and Seal Beach piers, were chosen to test censusing techniques. In June and July 1962, four 2-man crews conducted various pilot procedures using a 16-hour day (0500 to 2100) as a sampling unit.

To obtain estimates of the number of units of fishing effort expended on a structure seven procedures were tried:

1) All fishermen on the pier at the beginning of the day were counted, and those entering and leaving the rest of the day were tallied.
2) Fishing poles and handlines in use at the beginning of the day were counted, and those carried by fishermen entering and leaving the rest of the day were tallied.
3) Only those poles and lines actively fishing (lines in the water, hooks being baited, fish being removed, or similar related acts) were counted.
4) All fishing poles and handlines on the pier were counted regardless of whether they were in actual use or not.
5) All people on the pier were counted irrespective of the activity in which they were engaged.
6) Only the people fishing on the pier were counted.
7) Every *n*th "group" of fishermen was interviewed upon leaving the pier for a given period of time. A "group" of fishermen consisted of one or more individuals.

The first two procedures were quickly abandoned because a "judgment factor" was introduced in deciding who was a fisherman; it was very difficult to count poles packed for transport; and for a number of other reasons.

The counts obtained by methods 3 to 6 were usually completed within a short period, 10 minutes or less, and were utilized in our computations as though they had been made at a given instant in time; thus they were given the name "instantaneous counts." These counts were made hourly.

Interviewing every *n*th fishing group (Item 7), combined with systematic sampling (Cochran, 1953), and the *ultimate cluster* technique (Hansen, Hurwitz, and Madow, 1953), showed promise and were tested further before a final sampling plan based on these concepts and experiences was adopted.

METHODS

Pier and Jetty Sampling Plan, 1963

We divided the calendar year into three 4-month periods, as follows:

Period	*Months*
I	January, February, March, April
II	May, June, July, August
III	September, October, November, December

The day was our primary sampling unit, and within each period we stratified by weekdays and weekend days (Saturday, Sunday, and holidays). Lesser holidays, such as Columbus Day, were treated ac-

cording to their occurrence: a weekday if they fell within the week, or a weekend day if they fell on Saturday or Sunday (Table 1).

TABLE 1

Stratification of Year (1963), Distribution of Sampling Effort, and Number of Units Sampled in the Southern California Pier and Jetty Survey

	Period I	Period II	Period III	
	Feb., Mar., April	May, June, July, Aug.	Sept., Oct., Nov., Dec.	Total
Number of days in stratum	89	123	122	334
Weekdays	61	86	83	230
Saturday, Sunday, and holidays	28	37	39	104
Sampling effort—man-days expended	100	119	134	353
Piers	56	59	66	181
Weekdays	33	32	34	99
Saturday, Sunday, and holidays	23	27	32	82
Jetties	44	60	68	172
Weekdays	27	32	36	95
Saturday, Sunday, and holidays	17	28	32	77
Number of units in sampling frame	38	39	39	
Piers	22	22	22	
Jetties	16	17	17	
Number of units sampled one or more times	36	39	39	
Piers	20	22	22	
Jetties	16	17	17	

The total number of sample days varied between periods because: (i) the month of January was used to formulate the sampling plan, and (ii) we made adjustments, based on experience, in the time allowed for compensating time off, data processing, and emergencies.

Cochran's (1953) formula for optimum allocation was used as a guideline in determining the distribution of available sampling effort between weekdays and weekend days in each of the pier and jetty strata.

$$n_h = n \frac{N_h S_h}{N_h S_h + N_w S_w}$$

where

n_h	number of weekend days and holidays to be sampled
n	number of man days available for sampling
N_h	number of weekend days and holidays
S_h	standard deviation of weekend days and holidays
N_w	number of weekdays
S_w	standard deviation of weekdays

The distribution of sampling effort between weekdays and weekend days for Period I was based on an estimated standard deviation ratio of 1:1.5 (from 1962 experiences). For Periods II and III this ratio was modified to 1:2 (reflecting Period I experiences). The resulting

schedule indicated that for Periods I, II, and III we should divide the available sampling effort as follows: weekdays, 60, 64, and 72 man-days; weekend days, 40, 56, and 64 man-days. Unforeseen events, however, caused us to deviate from the prearranged schedule. Thus, the actual total expenditure of man-days of sampling in Periods I, II, and III was 100, 119, and 134 (Table 1).

FIGURE 1—Approximate geographical locations of ocean piers available to the public for sport fishing in 1963. Random samples were drawn from this population to estimate the total sportfishing effort and catch from these structures in 1963.

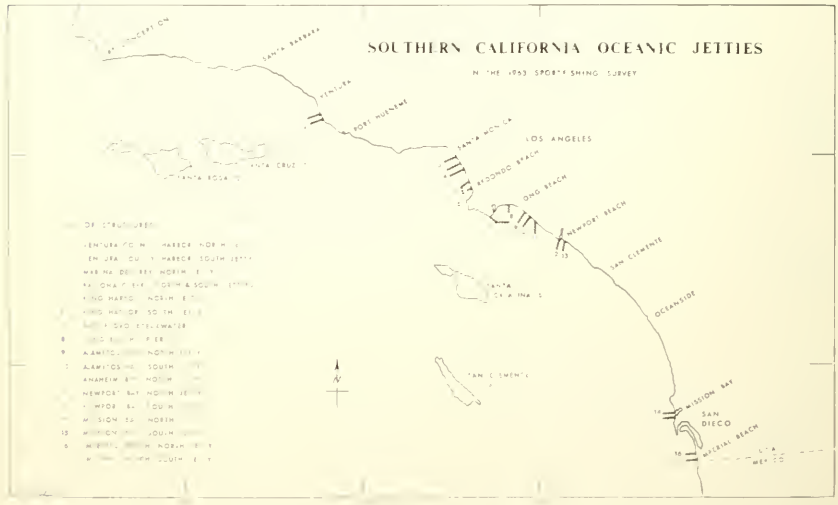

FIGURE 2—Approximate geographical locations of ocean jetties available to the public for sport fishing in 1963. Random samples were drawn from this population to estimate the total sportfishing effort and catch from these structures in 1963.

The distribution of sampling effort between piers and jetties in Period I was determined randomly, since they were grouped into a single stratum. In Periods II and III, when the piers and jetties were separated into individual strata, the effort was assigned on an equal basis.

The Period I sampling frame was composed of 38 piers and jetties. These were grouped by proximity of location into 19 clusters of two structures each (Figures 1 and 2). The San Pedro breakwater was not sampled because harbor dredging activities restricted its use. In Periods II and III, the 22 piers and 17 jetties were separated into 11 clusters of piers and 9 clusters of jetties. The San Pedro breakwater, one of the jetty clusters, was sampled as a single unit because of its length.

The pier groups were numbered consecutively and two were chosen at random, without replacement, for each sampling day. The sample day, arbitrarily chosen to range from 0630 to 1830, was divided into six, 2-hour sampling units.

The fishing activity for each 12-hour day was estimated by drawing a systematic sample of two, 2-hour intervals for each structure in a pier group. The starting time for pier "A" was chosen from the morning time intervals; the afternoon sampling interval started 6 hours later:

Morning sampling intervals	*Afternoon sampling intervals*
0630–0830	1230–1430
0830–1030	1430–1630
1030–1230	1630–1830

Pier "B's" starting time was chosen from the two remaining morning intervals; its second sampling interval also followed 6 hours later. All selections were made randomly.

The various components of this multistage sampling plan are: 1st stage, days; 2nd stage, cluster of structures; 3rd stage, hours in the selected day; and 4th stage, groups of fishermen.

In practice, sampling required that the clerk arrive at each structure on time (0630, 0830, or 1030). Instantaneous counts of all fishing poles or handlines in actual use were made on the hour within each period sampled; for example, in the interval 0630 to 0830, instantaneous counts were made at 0700 and 0800. On long jetties, where it took 35 minutes or more to traverse the structure, only one count was made per period, usually during the first hour.

Fishermen interviews were made during the entire 2-hour sampling interval except for the time spent on instantaneous counts, or when a portion of the last 30 minutes of the period was used to travel to the next structure. A predetermined fraction of fishing parties was interviewed as it left the pier. The interview fraction changed from day to day as conditions warranted (appropriate notations were made for the necessary adjustments in the computations). The census clerk recorded the type of structure, time of interview, time party started fishing, number of people in party who fished, number of fishing poles and handlines in party, and numbers and kinds of fish caught. Separate tallies were made of fish retained and discarded. Every effort was made to examine the catch for species identification and enumeration.

Estimation Procedures

The sampling plan was explicitly designed to permit computation of use and catch parameters in several ways. We believe, however, that the most straightforward estimates of the desired parameters are derived from the interview data collected from the sampled fishing parties.

Estimation procedures are best exemplified by the methods used to estimate the total man-hours of fishing expended by pier fishermen. The expansion procedure for a stratum of weekdays or weekend days, beginning with the man-hours of fishing expended by interviewed fishing parties on a structure during a sampled day is:

$$x_{hij} = f_{hij} g_{hij} \Sigma x_{hijk} \qquad k = 1, \ldots, m$$

$$x_{hi} = \frac{U}{u} \Sigma x_{hij} \qquad j = 1, \ldots, u$$

$$x_h = \frac{N}{n} \Sigma x_{hi} \qquad i = 1, \ldots, n$$

where

x_{hij} estimated man-hours of fishing expended in the hth stratum, during the ith sampling day, on the jth structure

f_{hij} reciprocal of fraction of day sampled in the hth stratum, on the ith day, and on the jth structure (the reciprocal would be 3 if 4 hours, out of a 12-hour day, were sampled)

g_{hij} reciprocal of fraction of parties sampled on the jth structure, on the ith day, in the hth stratum

x_{hijk} number of man-hours fished by the kth fishing party on the jth structure, during the ith day in the hth stratum

x_{hi} estimated man-hours of fishing expended during the ith day on all sampled structures of the hth stratum

U total number of piers or jetties in sampling frame in the hth stratum

u number of piers or jetties sampled on ith day in the hth stratum

x_h estimated man-hours of fishing expended during the hth stratum

N total number of days in hth stratum

n number of days sampled in hth stratum

m number of parties of fishermen interviewed on the jth structure on the ith day

h 1, 2, stratum of weekdays or weekend days

To estimate the man-hours of fishing for a period (e.g., group of months), sum the appropriate stratum estimates: weekdays, piers; weekend days, piers; weekdays, jetties; and weekend days, jetties. The estimate for the year is obtained by summing the estimates for the periods. Estimates for other time intervals or structural groupings (such as weekdays or piers for a year) can be obtained by summing the appropriate strata estimates.

The methods we used to calculate the variance of the estimates were essentially those of Hansen, Hurwitz, and Madow (1953). However, the variance formula associated with the ultimate cluster technique tends to overestimate the variance because the finite multiplier is not used. The procedure, using the example of man-hours of fishing, is:

$$v_h = N^2 \left[\frac{\Sigma x_{hi}^2 - \frac{(\Sigma x_{hi})^2}{n}}{n(n-1)} \right]$$

where

v_h is the estimated variance of the estimated man-hours of fishing for a stratum of weekdays or weekend days

RESULTS

Our estimates of sportfishing catch and effort from southern California piers and jetties are not amenable to comprehensive analysis for trends because there is no backlog of historical data. Our data indicate that structures located close to metropolitan areas are used intensively—a wholly predictable outcome. Our figures do illustrate the magnitude or degree to which these structures are used, and provide a base for current and future evaluations. For example, the California Wildlife Conservation Board utilized data gathered by the Department's northern and southern California surveys in deliberating plans to construct new oceanic piers; several were either completed or under construction in late 1964 (California Wildlife Conservation Board, 1964).

Effort Analysis

The estimated catch of 1.86 million fish in 5.1 million man-hours of fishing is a minimal value because sport fishing occurred on a number of structures not included in the survey. Imperial Beach pier, for example, was not sampled because it did not become operative until the closing days of the survey—initial use was reported to be very heavy. Sport fishing also occurred on some of the industrial piers despite the owners' prohibition; although this effort and the resulting catch was small, it was real and if known would be added to the total estimates. Finally, our estimated values are not indicative of an entire year's activity because the survey encompassed only the 11-month period February through December (Table 2).

Another anticipated outcome was the significantly larger expenditure of effort during the late spring and summer (Period II) than during the rest of the year (Periods I and III): 2.77 million man-

TABLE 2

Estimated Sport Fishing Effort and Catch from Piers and Jetties in Southern California in 1963 [1]

	Estimated man-days of fishing	S.E.	Estimated man-hours of fishing	S.E.	Estimated catch in numbers of fish	S.E.	Estimated catch per man-day of fishing	Estimated catch per man-hour of fishing
February, March, April (Period I)								
Piers and jetties[2]	279,192	35,286	876,080	126,303	430,237	71,225	1.541	0.491
San Pedro breakwater[3]								
May, June, July, August (Period II)								
Piers	574,982	53,177	2,198,053	224,335	754,975	102,230	1.313	0.343
Jetties	112,053	13,728	488,732	51,826	157,716	25,750	1.410	0.322
San Pedro breakwater	18,626	3,818	81,865	18,341	29,113	5,788	1.561	0.356
Totals	735,661	55,343	2,768,650	231,016	941,834	105,582	1.280	0.340
September, October, November, December (Period III)								
Piers	318,151	40,059	1,213,557	169,451	380,378	15,899	1.195	0.313
Jetties	61,710	9,827	213,182	35,830	98,153	20,601	1.521	0.461
San Pedro breakwater	6,362	530	19,056	2,030	4,591	1,686	0.721	0.240
Totals	389,226	41,250	1,445,793	173,213	483,422	50,338	1.242	0.334
Grand Totals	**1,404,079**	**76,394**	**5,090,523**	**315,125**	**1,855,493**	**136,917**	**1.321**	**0.364**

[1] The estimates cover only 11 months, February 1 through December 31, 1963. Period I spans 3 months, while Periods II and III are each 4 months long.
[2] In Period I piers and jetties were mixed within clusters, so it is impossible to make separate calculations for each type.
In Periods II and III, like structures were clustered together permitting separate and independent estimates for each.
[3] The San Pedro breakwater was closed to fishing during this period.

hours, vs. 0.88 and 1.45 million, respectively. Longer days, mild weather, and school vacation account for the differences. In Period II, fishermen expended 54.4% of the total effort for the year, and accounted for 50.7% of the total catch (Table 3).

TABLE 3

The Total Effort and Catch (Percentage) by Type of Structure and Period

	Period I	Period II	Period III
	Feb., Mar., April	May, June, July, Aug.	Sept., Oct., Nov., Dec.
Effort			
Piers		43.2	23.8
Jetties		11.2	4.6
Totals	17.2	54.4	28.4
Catch			
Piers		40.7	20.5
Jetties		10.0	5.6
Totals	23.2	50.7	26.1

The relationship between piers and jetties was determinable only for the months of May through December. Our data show that 67.0% of the total effort was expended on piers, and that pier fishermen succeeded in taking 61.2% of the total catch.

Catch Analysis

At least 49 animal species, belonging to 26 family groups, were captured from southern California piers and jetties during 1963 (Tables 4 and 5). The actual number of species caught from these structures was somewhat higher because catches were not always completely identified, and some species that did not appear in our survey were noted.

TABLE 4

Estimated Fish Catch by Family and Species from Piers and Jetties in 1963

Family Species	Period I Piers and jetties	Period II Piers	 Jetties	Period III Piers	 Jetties	Totals
1. Requiem sharks						**754**
Smoothhound unidentified	301	118		61		483
Leopard shark		271				271
2. Guitarfishes						**650**
Thornback	112		86			198
Shovelnose guitarfish	161	63	228			452
3. Herrings						**1,581**
Pacific sardine	386	1,080		115		1,581
4. Anchovies						**29,686**
Northern anchovy	52	22,559	117	6,958		29,686
5. Salmons						**239**
Silver salmon				239		239
6. Sea Basses						**45,921**
Kelp bass	1,624	3,783	20,856	910	4,433	34,606
Sand bass	2,482	1,066	3,540	711	2,570	10,399
Bass unidentified	269	249	536	102	660	1,816
7. Jacks						**4,030**
Jack mackerel	113	2,278		1,577	62	4,030
8. Grunts						**13,112**
Sargo	991	1,704	1,317	1,666	2,437	8,145
Salema	105	3,782		1,080		4,967
9. Croakers						**752,850**
Black croaker	866	244	654	195	199	2,158
White seabass	378	4,026		4,147		8,551
White croaker	93,600	121,154	39,389	71,751	13,108	342,002
California corbina	466	2,759	1,774	1,472	1,124	7,595
Spotfin croaker	760	7,468	58	5,297	1,138	14,721
Queenfish	78,344	231,137	13,173	39,101	1,137	362,892
Yellowfin croaker	337	5,178	491	6,016	32	12,057
Croaker unidentified	955	225		1,694		2,874
10. Halfmoons						**3,676**
Halfmoon	392	136	554	981	1,613	3,676
11. Nibblers						**31,448**
Opaleye	6,876	334	11,711	392	12,135	31,448
12. Surfperches						**412,736**
Barred surfperch	7,286	8,851	563	6,828	462	23,990
Shiner perch	48,382	36,093	15,084	19,331	14,078	132,968
Black perch	25,966	8,733	13,415	5,562	11,088	64,764
Walleye surfperch	52,263	32,632	7,315	41,092	7,909	141,151
Rainbow seaperch	68	604	107	154		933
Dwarf perch	45		49			94
White seaperch	7,888	1,624	1,330	4,477	2,450	17,769
Rubberlip perch	2,545	638		942	378	4,503
Pile perch	6,098	1,963	875	3,305	2,030	14,271
Perch unidentified	1,691	199	112	9,625	716	12,293
13. Damselfish						**105**
Blacksmith	52		53			105
14. Mackerels & Tunas						**345,505**
Pacific mackerel	3,133	5,280	561	15,365	2,330	56,669
Pacific bonito	50,338	156,197	37,797	32,669	6,467	283,068
Mackerel unidentified		136		5,583	49	5,768
15. Rockfishes						**10,702**
Sculpin	2,342	1,954	2,139			6,735
Blue	107					107
Rockfish unidentified	1,722	482	332	1,090	234	3,860
16. Sablefishes						**3,523**
Sablefish	59	3,464				3,523
17. Sculpins						**6,790**
Pacific staghorn sculpin	877	194	87	562		1,720
Cabezon	1,877	388	2,202	224	379	5,070
18. Clingfishes						**672**
Giant kelpfish		222	337		113	672
19. Butterfishes						**7,887**
Pacific pompano		2,885	838	1,280	2,884	7,887
20. Barracudas						**17,351**
California barracuda	1,786	12,557	1,030	1,916	62	17,351
21. Silversides						**72,187**
Topsmelt	1,212	6,784	1,137	3,538	888	13,559
Jacksmelt	6,060	14,518	924	22,449	1,955	45,906
California grunion	140	303				743
Silversides unidentified	446	1,910	56	9,201	336	11,979
22. Flounders						**71,654**
Sanddab unidentified	1,948	4,017		1,546	56	7,567
Bigmouth sole	354		105			459
California halibut	5,329	35,691	3,757	11,708	448	56,933

TABLE 4—Continued

Estimated Fish Catch by Family and Species from Piers and Jetties in 1963

Family Species	Period I	Period II		Period III		
	Piers and jetties	Piers	Jetties	Piers	Jetties	Totals
Fantail sole	441	334	39	218		1,032
Arrowtooth flounder	71					71
Diamond turbot	1,883	1,291	674	116		3,961
Starry flounder	55					55
Turbot unidentified	132		56	106		294
Flounder unidentified	991	111	125	52		1,282
23. Cusk eels						190
Cusk eel unidentified	52			138		190
24. Toadfishes						424
Midshipman unidentified	162		128	61	70	424
25. Unidentified Fish Species	423	2,149	351	6,644	850	10,317
26. Crabs						10,523
Crabs unidentified	3,253	121	887	95	6,164	10,523
Totals	430,237	754,975	186,859	389,578	103,044	1,955,193

TABLE 5

Common and Scientific Names of Fishes Caught by Pier and Jetty Fishermen in Southern California During 1963

Common names	Scientific names
Requiem sharks	Carcharhinidae
Leopard shark	*Triakis semifasciata* Girard
Guitarfishes	Rhinobatidae
Thornback	*Platyrhinoidis triseriata* (Jordan and Gilbert)
Shovelnose guitarfish	*Rhinobatos productus* (Ayres)
Herrings	Clupeidae
Pacific sardine	*Sardinops caeruleus* (Girard)
Anchovies	Engraulidae
Northern anchovy	*Engraulis mordax* Girard
Salmon	Salmonidae
Silver salmon	*Oncorhynchus kisutch* (Walbaum)
Sea basses	Serranidae
Kelp bass	*Paralabrax clathratus* (Girard)
Sand bass	*Paralabrax nebulifer* (Girard)
Jacks	Carangidae
Jack mackerel	*Trachurus symmetricus* (Ayres)
Grunts	Pomadasyidae
Sargo	*Anisotremus davidsoni* (Steindachner)
Salema	*Xenistius californiensis* (Steindachner)
Croakers	Sciaenidae
Black croaker	*Cheilotrema saturnum* (Girard)
White seabass	*Cynoscion nobilis* (Ayres)
White croaker	*Genyonemus lineatus* (Ayres)
California corbina	*Menticirrhus undulatus* (Girard)
Spotfin croaker	*Roncador stearnsi* (Steindachner)
Queenfish	*Seriphus politus* Ayres
Yellowfin croaker	*Umbrina roncador* Jordan and Gilbert
Halfmoons	Scorpidae
Halfmoon	*Medialuna californiensis* (Steindachner)
Nibblers	Girellidae
Opaleye	*Girella nigricans* (Ayres)
Surfperches	Embiotocidae
Barred surfperch	*Amphistichus argenteus* Agassiz
Shiner perch	*Cymatogaster aggregata* Gibbons
Black perch	*Embiotoca jacksoni* Agassiz
Walleye surfperch	*Hyperprosopon argenteum* Gibbons
Rainbow seaperch	*Hypsurus caryi* (Agassiz)
Dwarf perch	*Micrometrus minimus* (Gibbons)
White seaperch	*Phanerodon furcatus* Girard
Rubberlip perch	*Rhacochilus toxotes* Agassiz
Pile perch	*Rhacochilus vacca* (Girard)
Damselfishes	Pomacentridae
Blacksmith	*Chromis punctipinnis* (Cooper)
Mackerels and tunas	Scombridae
Pacific mackerel	*Scomber diego* Ayres
Pacific bonito	*Sarda chiliensis* (Cuvier)
Rockfishes	Scorpaenidae
Sculpin	*Scorpaena guttata* Girard
Blue rockfish	*Sebastodes mystinus* (Jordan and Gilbert)
Sablefishes	Anoplopomatidae
Sablefish	*Anoplopoma fimbria* (Pallas)
Sculpins	Cottidae
Pacific staghorn sculpin	*Leptocottus armatus* Girard
Cabezon	*Scorpaenichthys marmoratus* (Ayres)
Clinids	Clinidae
Giant kelpfish	*Heterostichus rostratus* Girard
Butterfishes	Stromateidae
Pacific pompano	*Palometa simillima* (Ayres)

TABLE 5—Continued

Common and Scientific Names of Fishes Caught by Pier and Jetty Fishermen in Southern California During 1963

Common names	Scientific names
Barracudas	Sphyraenidae
California barracuda	*Sphyraena argentea* (Girard)
Silversides	Atherinidae
Topsmelt	*Atherinops affinis* (Ayres)
Jacksmelt	*Atherinopsis californiensis* Girard
California grunion	*Leuresthes tenuis* (Ayres)
Lefteye flounders	Bothidae
Bigmouth sole	*Citharichthys xanthostigma* Gilbert
California halibut	*Paralichthys californicus* (Ayres)
Fantail sole	*Xystreurys liolepis* Jordan and Gilbert
Righteye flounders	Pleuronectidae
Arrowtooth flounder	*Atheresthes stomias* (Jordan and Gilbert)
Diamond turbot	*Hypsopsetta guttulata* (Gilbert)
Starry flounder	*Platichthys stellatus* (Pallas)

The three fish families contributing heaviest to the pier and jetty fisherman's bag were: (i) croakers, (ii) surfperches, and (iii) mackerels and tunas. The predominant species in each of these families were: (i) queenfish, (ii) walleye surfperch, and (iii) Pacific bonito. Croakers contributed more than any other family (40.6% of the total), with two species, queenfish and white croaker, contributing 19.6 and 18.4%, respectively (Table 6). In actuality, these two species are dominant not only among the catch of croakers, but among all species regardless of family.

TABLE 6

Catch Composition by Predominant Families and Species from Piers and Jetties, 1963

Family and species	Percentage of total catch
Croakers	**40.6**
Queenfish	19.6
White croaker	18.4
Other	2.6
Surfperch	**22.2**
Walleye surfperch	7.6
Shiner perch	7.1
Other	7.5
Mackerels and tunas	**18.6**
Pacific bonito	15.3
Pacific mackerel	3.0
Other	.3
All others	**18.6**
Totals	100.0

A cursory examination of the data reveals that the same species of fish are taken from piers as from jetties at one time or another; however, by regrouping the species according to the volume landed (i.e., using 60% of the total catch of each species as a guide), a majority of these (28) is taken from piers (Table 7). Either piers or jetties could yield the major portion of the catch of four other species, including the desirable sargo and corbina. Finally, 11 species are taken primarily from jetties, the most significant being kelp and sand bass, opaleye, halfmoon, and cabezon.

TABLE 7

Fish Catch from Piers and Jetties 1963, Grouped by Volume Landed

Catch from piers greater than 60% of total catch of each species	Catch from piers or jetties ranges between 40 and 60% of total catch of each species	Catch from jetties greater than 60% of total catch of each species
Pacific sardine	Sargo	Kelp bass
Northern anchovy	California corbina	Sand bass
Silver salmon	Sculpin (rockfish)	Black croaker
Jack mackerel	Pacific pompano	Halfmoon
Salema		Opaleye
Rubberlip perch		Black perch
White croaker		Dwarf perch
White seabass		Blacksmith
Spotfin croaker		Giant kelpfish
Queenfish		Cabezon
Yellowfin croaker		Bigmouth sole
Barred surfperch		
Shiner perch		
Walleye surfperch		
Rainbow seaperch		
White seaperch		
Pile perch		
Pacific mackerel		
Pacific bonito		
Sablefish		
Pacific staghorn sculpin		
California barracuda		
Topsmelt		
Jacksmelt		
Grunion		
California halibut		
Fantail sole		
Diamond turbot		

RECOMMENDATIONS

The importance of piers in the sportfishing and outdoor recreational picture has been recognized for many years. The two latest sportfishing surveys of California marine waters have not only documented the significant role played by these structures (Miller and Gotshall, 1965), but were of material assistance to the California Wildlife Conservation Board in implementing its program for pier development. This pier development program should be continued and strengthened. There are still portions of the coast where new piers would fulfill recreational needs. In other areas, improvement of a number of existing structures would insure future fishing opportunities.

Five species of fish (queenfish, white croaker, bonito, walleye surfperch, and shiner perch), contributed over 68% of the total 1963 catch of fish from piers and jetties. Should the need arise, our present understanding of these five species is insufficient for intelligent management. Thus, biological investigations of these species should be undertaken to provide the basic data required for sound resource management.

Catch and effort data (commercial and sportfishing partyboat landings) routinely collected by the California Department of Fish and Game do not reveal for the above five species, as well as many others, changes and trends in population size or structure. To close this gap in our knowledge of our marine resources, periodic surveys should be conducted to assess sportfishing effort and catch from piers, jetties, the shore line, and private vessels. These surveys should be based on probability sampling theory, should cover the entire coast of California, and should be spaced not more than 5 years apart.

In conducting future surveys it is essential to know beforehand how the results are to be used, so a sampling plan can be developed to accomplish the objectives. If, as in our case, money and manpower are the prime considerations, the precision of the estimate suffers and may even be unobtainable. An intuitive estimate is, of course, a minimal alternative.

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AGE, LENGTH COMPOSITION, AND CATCH LOCALITIES OF SARDINE LANDINGS ON THE PACIFIC COAST OF THE UNITED STATES AND MEXICO IN 1962–63[1]

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The California catch of Pacific sardines, *Sardinops caeruleus* (Girard), during the 1962–63 season was the smallest recorded since 1916–17. In central California, 1,199 tons were taken August 1, 1962, through March 1, 1963; and in southern California, 1,477 tons were caught September 1 through March 1, 1963, for a season total of 2,676 tons. This, plus the 1962 interseason catch of 1,427 tons, brought the 1962–63 period total to 4,103 tons.

Baja California sardine landings in recent years have exceeded those of California. During the 1962–63 season (equivalent to the September 1 – March 1 season of southern California), 8,130 tons were landed. The 10,044 tons taken during the interseason brought the period total to 18,174 tons.

Central California landings were dominated by age-4 and age-5 fish (1958 and 1957 year classes), which contributed about 83% of the catch. Southern California landings were dominated by age-3 and age-4 fish (1959 and 1958 year classes), which also accounted for about 83% of the catch. In both northern and central Baja California, age-3 fish contributed over 50% of the landings. Age-2 and age-4 fish (1960 and 1958 year classes) also contributed significantly, accounting for about 40% of the numbers landed.

INTRODUCTION

This is the 17th report in a series giving the age and length composition of the catch of Pacific sardines off the Pacific Coast of North America. The data are compiled jointly by the U.S. Bureau of Commercial Fisheries and Marine Resources Operations, California Department of Fish and Game. The reports have been published on a seasonal basis since 1941–42.

We acknowledge the assistance given by Robert S. Wolf, U.S. Bureau of Commercial Fisheries, and by Anita E. Daugherty and Harold Hyatt, California Department of Fish and Game. William W. Hatton, California Academy of Sciences, gathered fish samples and landing statistics from the Baja California fishery. We also thank the cannery personnel and fishing boat captains who cooperated with our waterfront representatives.

THE FISHERY

Previous publications on the age and length composition of the Pacific sardine catch focused attention on the California fishery, which accounted for the major landings. Supplementary information on the sardine fisheries of the Pacific Northwest (1941–42 through 1948–49) and Baja California (1951–52 to date) were included. Now the Pacific Northwest fishery is nonexistent; California sardine landings have declined drastically; and, in recent years, the Baja California fishery has been the major contributor to sardine landings on the Pacific Coast. Since 1958, the area of greatest sardine catch has shifted gradually

[1] Submitted for publication September 1966.

from northern Baja California (Ensenada) to central Baja California (Cedros Island), and more recently to southern Baja California (Puerto Adolfo Lopez Mateos).

During the 1962–63 cannery season (August 1 through March 1), 1,199 tons of sardines were landed in central California.[2] In southern California, 1,477 tons were landed during the cannery season (September 1 through March 1). Thus, the statewide 1962–63 season sardine catch of 2,676 tons was the smallest recorded since 1916–17. During the interseason, March 2, 1962, to the beginning of the central and southern California seasons, total landings were 1,427 tons. This amount brought the statewide total to 4,103 tons for the 1962–63 period.

Landings during the cannery season include deliveries to both the cannery and fresh-fish markets. Most of the fish in the latter are frozen and sold for bait, chiefly in the San Francisco region, where sport fishermen highly regard sardines as bait.

Interseason sardine landings include fish sold not only for bait, but also for canning as a special pack. This pack, first permitted in 1929, gives canners an opportunity to pack sardines in small cans to compete with imported sardines. The privilege was suspended by the California Legislature in 1949 because of the decline in sardine landings, but was reinstated June 1, 1961. Only one southern California processor took advantage of this during the 1962 interseason.

TABLE 1
Calendar Dates of Lunar Months During the 1962–63 Period

Lunar month	Lunar period*	Dates
"March"	524	February 20 (1962)–March 20
"April"	525	March 21–April 18
"May"	526	April 19–May 18
"June"	527	May 19–June 16
"July"	528	June 17–July 16
"August A"†	529	July 17–August 14
"August B"	530	August 15–September 13
"September"	531	September 14–October 12
"October"	532	October 13–November 11
"November"	533	November 12–December 11
"December"	534	December 12–January 10 (1963)
"January"	535	January 11–February 8
"February"	536	February 9–March 10

* Lunar months have been numbered serially since "November" 1919.
† Because lunar months are shorter than calendar months it is necessary to add an additional lunar month every three years to compensate.

[2] Landings were allowed on March 2 in central and southern California.

In Baja California, sardine fishing is permitted throughout the year. For purposes of comparison, the fishing period is divided into season and interseason, so the dates will correspond with those of southern California. Season and interseason landings amounted to 8,130 and 10,044 tons, respectively, for a 1962–63 period total of 18,174 tons.

CENTRAL CALIFORNIA

In central California (Point Arguello northward), the season opened August 1, 1962, and ended March 1, 1963. Fishing started promptly in central California, with a tentative price of $50 per ton for sardines, the price paid during the preceding season. The price for jack mackerel, *Trachurus symmetricus*, and Pacific mackerel, *Scomber diego*, was also continued at the level of the preceding season, $42.50 per ton. On October 8, to conform to southern California quotations, the price was set at $60 per ton for sardines, $42.50 for mackerel, and $47.50 for mixed sardines and mackerel. During the last 14 days of the "August A" lunar period (Table 1), 384 tons were landed.

The catch of 424 tons during "August B" was the highest of the season. The "September" catch of 297 tons was followed by 53 tons during "October". Fishing during successive lunar periods yielded smaller catches, to a low of 6 tons during "January". The total for the region was 1,199 tons.

Nearly 95% of the central California catch was taken south of Monterey Bay, between Point Sur and Morro Bay. Most of the tonnage was taken off Point Lopez, about halfway between Point Sur and Piedras Blancas. The remainder came from Monterey Bay (Figure 1, Table 2).

TABLE 2

Sardine Catch by General Fishing Areas for 1962–63 Period

General areas	Block numbers	Interseason*		Season†		Total	
		Pounds	Percentage	Pounds	Percentage	Pounds	Percentage
Point Arena	401-421	0	0.0	0	0.0	0	0.0
Bodega Head	422-445	0	0.0	94	T	94	T
San Francisco	446-471	0	0.0	0	0.0	0	0.0
Pigeon Point	472-506	0	0.0	0	0.0	0	0.0
Monterey	507-531	3,966	0.1	114,003	2.1	117,969	1.4
Point Sur	532-552	0	0.0	1,387,067	25.9	1,387,067	16.9
Piedras Blancas	553-606	0	0.0	80,150	1.5	80,150	1.0
Point Buchon	607-630	0	0.0	184,500	3.5	184,500	2.2
Point Sal	631-648	0	0.0	0	0.0	0	0.0
Santa Barbara	651-657, 665-671	0	0.0	0	0.0	0	0.0
Port Hueneme	664, 680-683, 703-706, 722-725	0	0.0	437,857	8.2	437,857	5.3
Santa Cruz Island	684-690, 707-713, 726-732	0	0.0	404,517	7.6	404,517	4.9
Point Vicente	679, 701, 702, 718-721, 737-742	669,383	23.4	820,165	15.3	1,489,548	18.2
Oceanside	756-758, 801-804, 821-825	0	0.0	54,230	1.0	54,230	0.7
Santa Catalina Island	759-762, 805-808	192,700	6.8	120,787	2.3	313,487	3.8
Santa Barbara Island	743-745, 763-765, 809-811	0	0.0	964	T	964	T
San Nicolas Island	746-749, 766-769, 812-815, 833-836	0	0.0	194,506	3.6	194,506	2.4
San Diego	842-846, 860-864, 877-882	0	0.0	17,775	0.3	17,775	0.2
San Clemente Island	826-832, 847-853, 865-869	4,100	0.2	1,235	T	5,335	0.1
Tanner and Cortes Banks	854-855, 870-873, 888-891, 897	0	0.0	106,882	2.0	106,882	1.3
Totals by area		870,149	30.5	3,924,732	73.3	4,794,881	58.4
Pounds of unknown origin not included in above		1,984,680	69.5	1,426,442	26.7	3,411,122	41.6
Total catch		2,854,829	100.0	5,351,174	100.0	8,206,003	100.0

*Interseason: north of Pt. Arguello Mar. 2–July 31; south of Pt. Arguello Mar. 2–Aug. 31.
†Season: north of Pt. Arguello Aug. 1–Mar. 1; south of Pt. Arguello Sept. 1–Mar. 1.

Only 3 canneries operated in central California: 1 at San Francisco, 1 at Moss Landing, and 1 at Monterey. Nine lampara boats fished exclusively in central California; 6 purse seiners, 4 large (60 feet or over) and 2 small, also fished off southern California.

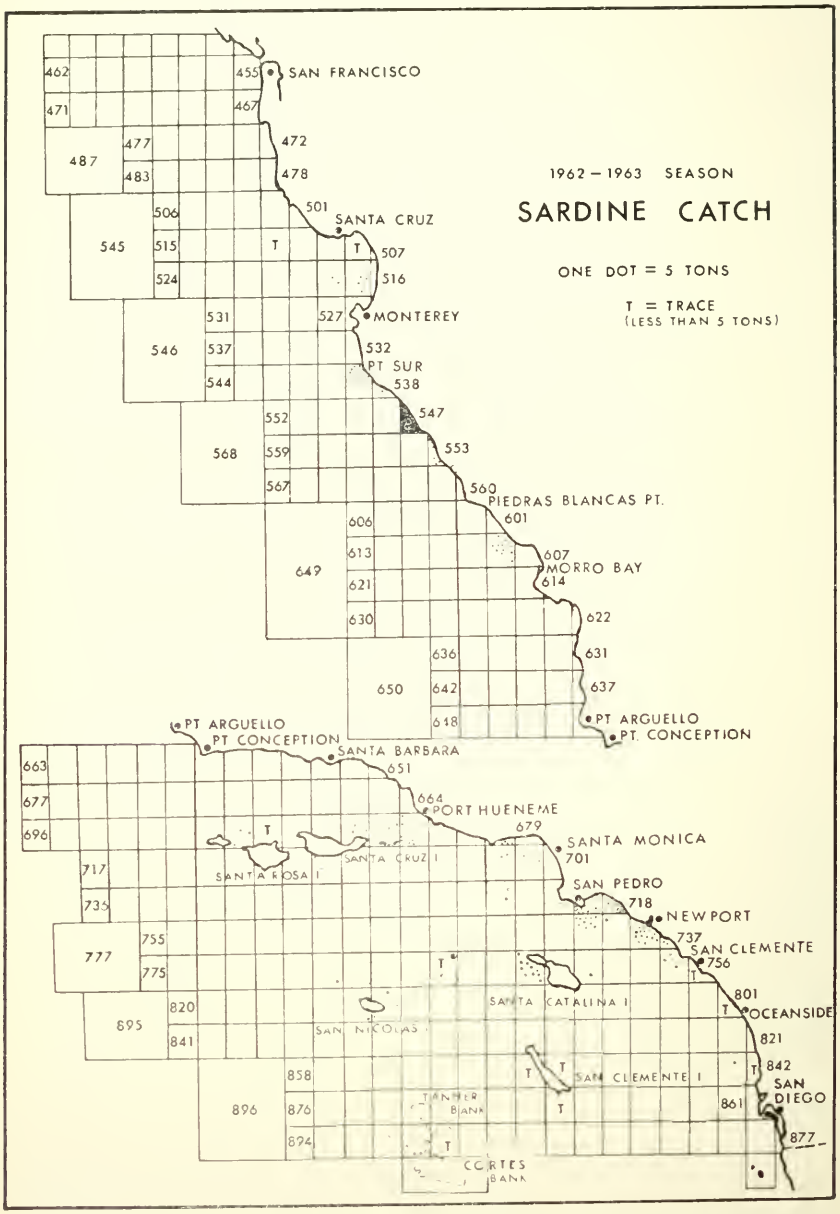

FIGURE 1—California sardine catch origins, 1962–63 season. Dots are placed in approximate locations, relative to land masses, where fish are known to have been taken.

SOUTHERN CALIFORNIA

The season opened September 1 in southern California. With the exception of a few boats, the fleet did not fish until the evening of October 8, when a price dispute was resolved. At that time the price was set at $60 per ton for sardines, $42.50 for mackerel, and $47.50 for mixed sardines and mackerel.

During "August B", 16 tons were landed, followed by 240 tons in "September". This was followed by a catch of 485 tons in "October". Subsequent landings during the "November" through "February" lunar periods ranged from 127 to 229 tons. The total for the region during the regular season was 1,477 tons.

Southern California sardines were taken along the coast from Port Hueneme to La Jolla, and from offshore islands and banks. The primary catch areas were near Port Hueneme; Santa Monica Bay; San Pedro; Newport; Santa Cruz and San Nicolas islands; and Cortes and Tanner banks (Figure 1, Table 2). Sardines were generally mixed with mackerel; only a few sets were made on "pure" schools of sardines.

As in 1961–62, 7 canneries operated in southern California: 1 at Oxnard and 6 in the Los Angeles-Long Beach Harbor area.

A total of 75 boats, comprising 41 large purse seiners and 34 small purse seiners and lampara boats, fished exclusively in southern California. In addition, 4 large and 2 small purse seiners also fished in central California.

BAJA CALIFORNIA

Seven canneries processed sardines in Baja California during the season: 5 at Ensenada, 1 at Isla Cedros, and 1 in southern Baja California at Puerto Adolfo Lopez Mateos. The southernmost cannery lies about 4 miles within Boca de la Soledad, about 35 miles northeast of Cabo San Lazaro (Figure 2).

The sardine fishery operates throughout the year off Baja California. Landings in the areas of northern Baja California (Ensenada), central Baja California (Isla Cedros), and southern Baja California (Puerto Adolfo Lopez Mateos) amounted to 8,130 tons during the season. The tonnage landed during the comparable period in 1961–62 was 8,551 tons. The 1962 interseason landings were 10,044 tons.

Weather conditions were generally favorable throughout the 1962–63 period; however, domestic demand for canned sardines was low, and fishing effort declined.

Ensenada canneries received about 75% of their sardines through transshipments by refrigerated vessel from central Baja California waters off Santo Domingo in Bahia Sebastian Vizcaino. The remaining portion came from the northern area between the United States-Mexico border and Punta Soledad. The cannery at Isla Cedros was supplied with fish caught in the waters of Bahia Sebastian Vizcaino. The cannery at Puerto Adolfo Lopez Mateos was supplied by purse seiners which ranged from Punta San Juanico south to Punto San Tosca. The majority of the catches came from Bahia Magdalena.

The Baja California fishing fleet consisted of 30 vessels that spent most of their time fishing for sardines and mackerel. The fleet was composed of large (60 feet and over) and small purse seiners, most of

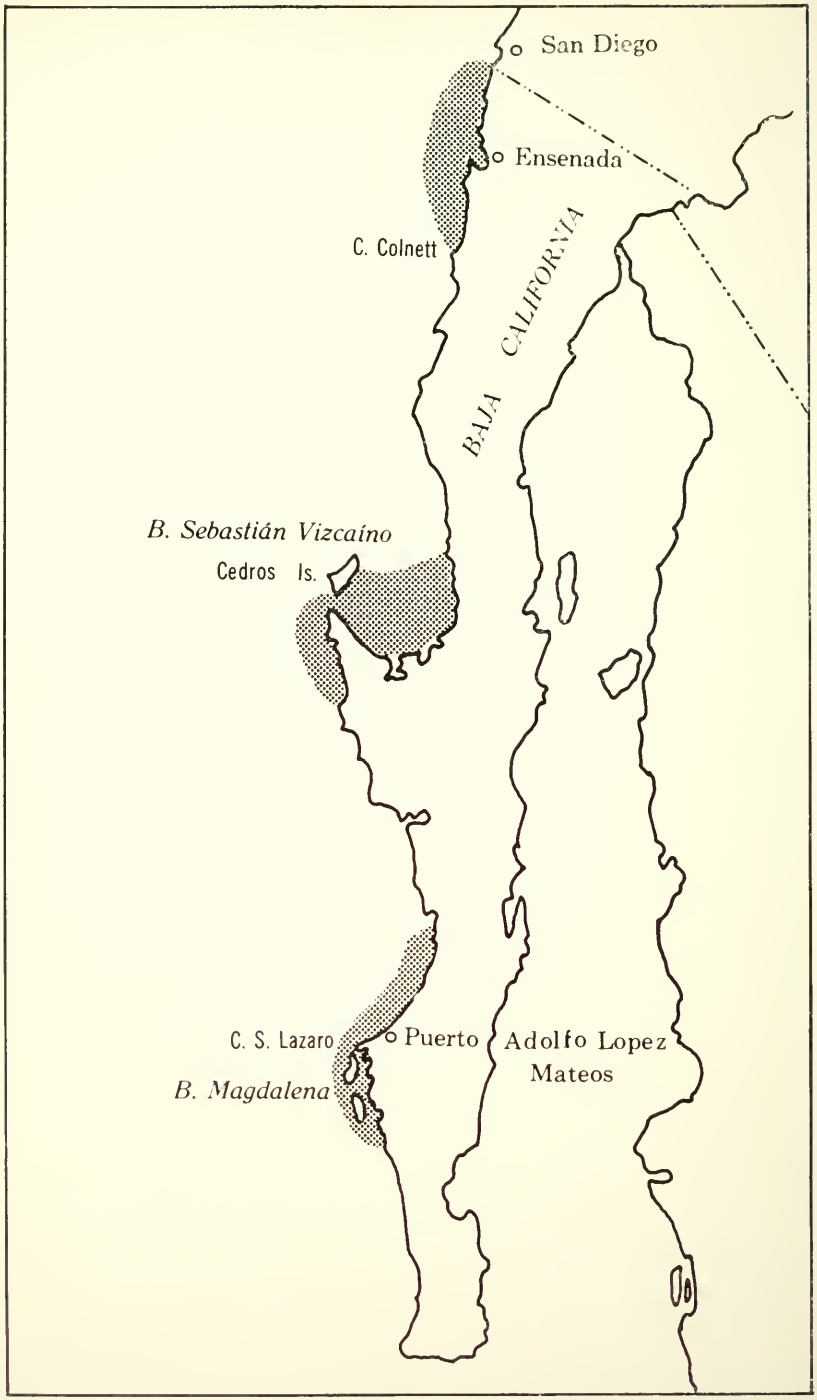

FIGURE 2—Baja California sardine catch areas, 1962–63 season. The shaded areas indicate locations where sardines were concentrated, as determined by fish sampling data and from information obtained from spokesmen of the sardine canneries.

them locally owned. Twenty-three were based at Ensenada, 4 at Isla Cedros, and 3 at Puerto Adolfo Lopez Mateos. Four of the Ensenada based vessels landed sardines at Isla Cedros during part of the year. Six of the larger Ensenada vessels are equipped with refrigerated holds, enabling them to fish in the Isla Cedros area and return their sardine catches to Ensenada. These vessels also are equipped with powerblocks for hauling in the purse seines. Occasionally the Baja California fleet was augmented by vessels from San Pedro, California.

The amount paid to the fishermen for sardines in Baja California varied with the operational status of their boats. Cannery-owned vessels received $32.60 per ton for sardines. Privately-owned vessels, usually owned and operated by Americans, received up to $42 per ton. One company, landing fish for another, received about $48 per ton. The price for mixed sardine and mackerel landings was about $32 per ton. The prices quoted are the maximums; however, the ranges were so slight that they are close to the averages for the period.

AGE AND LENGTH COMPOSITION

Each sardine length sample usually consists of 50 fish, measured to the nearest millimeter SL. Ten fish are taken randomly from each sample for age determinations. To estimate the year-class composition of a region's catch during a lunar month, three things are required: (i) an estimate of the number of fish landed (obtained by dividing total weight landed by the mean weight of the fish sampled); (ii) a summary of the age composition stratified by centimeters of length, and giving the numbers of fish by year class within each length stratum; and (iii) a length-frequency distribution of the total number of fish sampled, also stratified by cm intervals. The total number of fish measured in each length stratum of the frequency distribution is allocated to year classes in the same proportions as those aged in each length stratum. These data are then summed by year classes. The age or year-class composition of the catch is then obtained by allocating the estimated number of fish landed to year classes in the same proportions as in the year-class summation. Other details of the method are given by Felin and Phillips (1948).

Length samples for 1962–63 included 633 fish from central California landings, 1,100 from southern California, 700 from northern Baja California, and 900 from central Baja California. Although substantial landings of sardines are made in southern Baja California, they are not yet being sampled.

Two size groups were evident in samples from central and southern California (Figure 3), but the separation was less distinct in southern California. Single size groups occurred in northern and central Baja California.

Central California landings consisted primarily of large sardines landed during the "August A" through "October" periods. The lengths ranged from 224 to 266 mm, and averaged 245 mm; the average weight was 0.411 pounds. The 123 fish taken for age determinations consisted of 5 year classes: 1956, 1957, 1958, 1960, and 1961 (Table 3). Catches were dominated by 4- and 5-year-olds (1958 and 1957 year classes) which contributed 83% of the estimated numbers landed (Table 12).

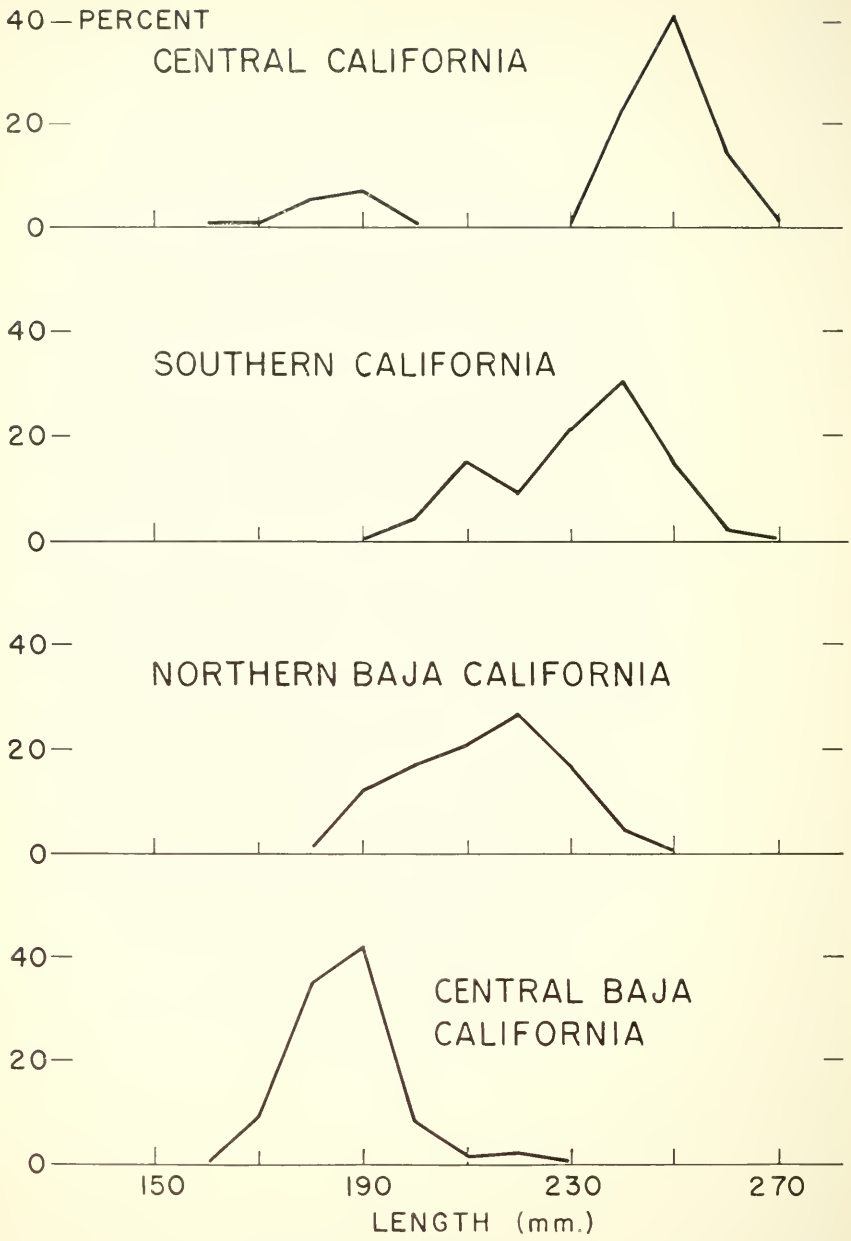

FIGURE 3—Percentage length composition of sardines sampled during the 1962–63 commercial season, by region of capture. Data are plotted at 10-mm intervals.

TABLE 3

Length Composition of Year Classes in Sardine Samples from the Central California Commercial Catch, 1962–63 Season

Standard length (mm)	Year class							Totals	
	1962	1961	1960	1959	1958	1957	1956	Aged	Measured
130									1
154									2
156									
158									1
160									
162									
164			1					1	1
166									1
168									
170									1
172		1						1	2
174		1	1					2	6
176			3					3	7
178		2	2					4	10
180			1					1	12
182			1					1	14
184			1					1	11
186			1					1	12
188			2					2	5
190		1						1	5
192									2
194			1					1	1
196			1					1	2
198			1					1	1
200									1
202									
204									
206									
208									
210									
212									
214									
216									
218									
220									
222									
224					1	1		2	3
226									
228									1
230									6
232					1	1		2	15
234						2		2	20
236					5		1	6	32
238					2	2	3	7	36
240					3	3		6	46

TABLE 3—Continued

Length Composition of Year Classes in Sardine Samples from the Central California Commercial Catch, 1962–63 Season

Standard length (mm)	Year class							Totals	
	1962	1961	1960	1959	1958	1957	1956	Aged	Measured
242					5	4	2	11	62
244					5	7	1	13	62
246					7	5		12	54
248					2	4	3	9	37
250					2	6	1	9	46
252					3	2	3	8	32
254					1	1		2	26
256					3	1		4	19
258						5		5	16
260					1	1	1	3	12
262					1			1	5
264									3
266									2
Totals		5	16		42	45	15	123	633
Mean lengths		178	182		245	246	246	246	245

Sardines in southern California samples ranged from 188 to 266 mm and had a mean of 228 mm; the average weight was 0.345 pounds (Table 4). Catches were dominated by 3- and 4-year-olds (1959 and 1958 year classes), which constituted about 83% of the landings. The 5- and 6-year-olds (1957 and 1956 year classes) contributed about 15 and 1%, respectively (Table 12).

TABLE 4

Length Composition of Year Classes in Sardine Samples from the Southern California Commercial Catch, 1962–63 Season

Standard length (mm)	Year class							Totals	
	1962	1961	1960	1959	1958	1957	1956	Aged	Measured
188									1
190									2
192									3
194				2				2	6
196				1				1	5
198				2				2	12
200				4				4	20
202				7	2			9	42
204				7				7	27
206				1				1	32
208				9	2			11	37
210				3				3	33
212				4				4	17
214				5	1			6	22
216				1	2	1		4	17
218				1	2			3	20
220				3	3			6	28
222				7		1		8	35
224				1	4			5	43
226				6	5	2		13	43
228				2	2			4	55
230				5	6	1		12	62
232				7	8	4		19	65
234				3	8	3	1	15	70
236				3	9	3	1	16	64
238				4	3	4		11	68
240				1	3	4		8	68
242				1	3	4	1	9	59
244				1	7			8	34
246					8	1		9	34
248				1	2	4		7	21
250				1	4	1		6	24
252					2	2		4	15
254									5
256									3
258									2
260									1
262									2
264									2
266									1
Totals				93	86	35	3	217	1,100
Mean lengths				218	234	238	237	228	228

As in preceding seasons, fish sampled in Baja California were smaller than those taken in California. Lengths of 700 sardines sampled from northern Baja California ranged from 172 to 248 mm and had a mean of 209 mm (Table 5). The weight averaged 0.316 pounds. The 3-year-olds (1959 year class) were dominant and contributed nearly 50% of the numbers aged. The 900 sardines from central Baja California were considerably smaller; lengths ranged from 152 to 226 mm and averaged 183 mm (Table 6). Here, too, the 3-year-olds (1959 year class) were dominant and contributed slightly over 50% of the number aged. Total landings from Baja California, when converted into numbers of fish, consisted mainly of 3-year-olds (1959 year class), but 2- and 4-year-olds did contribute significantly to the catch (Table 12).

The 1962 interseason landings in California were negligible. Measurements were obtained from only 101 fish in central California; lengths ranged from 228 to 274 mm (Table 7). The fish were sampled from May through July 1962, and only 25 were used in age analysis. The 1958 year class was the dominant contributor. Southern California landings, sampled during May and June, consisted of 250 fish from 186 to 256 mm long (mean 228 mm). The 1957 and 1958 year classes were the major contributors.

Interseason samples from northern Baja California catches consisted of 950 fish that ranged from 164 to 240 mm and averaged 203 mm (Table 9). Samples from central Baja California consisted of 700 fish ranging from 142 to 222 mm with a mean of 176 mm (Table 10). The interseason catch of Baja California was composed principally of the 1958 year class, 44%; the 1957 year class contributed 28% and the 1959 year class, 18% (Table 11).

TABLE 5

Length Composition of Year Classes in Sardine Samples from the Northern Baja California Commercial Catch, 1962–63 Season

Standard length (mm)	Year class							Totals	
	1962	1961	1960	1959	1958	1957	1956	Aged	Measured
172									1
174									
176									1
178									2
180									8
182									10
184				1				1	23
186			2					2	17
188			3					3	16
190			1	2		1		4	19
192				2	1			3	25
194			2	1				3	30
196			1	2				3	21
198				3				3	19
200				3	2			5	27
202				1	1			2	23
204			3	2	1	1		7	27
206			2	2	2	1		7	29
208			1	7	2			10	33
210				4	2			6	32
212				5	2			7	39
214				4	4	2	1	11	40
216			1	4	4	1		10	34
218				6	1			7	36
220			1	5	1			7	36
222				2	3		1	6	31
224				3	4	1		8	33
226			2	2	5			9	26
228			1	3	2			6	16
230					2			2	12
232			1		2			3	15
234			1	2				3	13
236									3
238					1			1	1
240									1
242									
244									
246									
248						1		1	1
Totals			22	66	42	8	2	140	700
Percentage			15.71	47.14	30.00	5.72	1.43	100.00	
Mean lengths			206	211	218	215	218	213	209

TABLE 6

Length Composition of Year Classes in Sardine Samples from the Central Baja California Commercial Catch, 1962–63 Season

Standard length (mm)	Year class							Totals	
	1962	1961	1960	1959	1958	1957	1956	Aged	Measured
152	--	--	--	--	--	--	--	--	1
154	--	--	--	--	--	--	--	--	--
156	--	--	--	--	--	--	--	--	1
158	--	--	--	--	--	--	--	--	1
160	--	--	--	--	--	--	--	--	2
162	--	--	1	1	--	--	--	2	5
164	--	--	--	--	--	--	--	--	8
166	--	--	1	--	1	--	--	2	7
168	--	--	2	3	1	--	--	6	26
170	--	--	3	3	--	1	--	7	36
172	--	--	2	2	--	--	--	4	38
174	--	--	3	11	2	--	--	16	60
176	--	--	3	3	3	--	--	9	65
178	--	--	2	7	--	--	--	9	87
180	--	--	6	9	4	--	--	19	76
182	--	--	1	6	3	2	1	13	87
184	--	--	2	11	7	1	--	21	89
186	--	--	3	6	3	3	--	15	74
188	--	--	7	6	6	3	1	23	73
190	--	--	2	8	1	--	--	11	51
192	--	--	1	3	--	--	--	4	32
194	--	--	--	2	--	1	--	3	15
196	--	--	--	1	--	1	--	2	9
198	--	--	--	1	--	--	--	1	11
200	--	--	--	--	--	--	--	--	5
202	--	--	--	2	--	--	--	2	7
204	--	--	--	--	--	--	--	--	1
206	--	--	--	2	--	1	--	3	3
208	--	--	--	--	--	--	--	--	2
210	--	--	--	--	1	--	--	1	2
212	--	--	--	1	--	--	--	1	3
214	--	--	--	--	--	--	--	--	1
216	--	--	--	--	--	1	--	1	4
218	--	--	--	--	1	--	--	1	8
220	--	--	--	1	1	--	--	2	4
222	--	--	--	--	--	--	--	--	3
224	--	--	--	1	--	--	--	1	2
226	--	--	--	--	--	--	--	--	1
Totals	--	--	39	90	34	14	2	179	900
Percentage	--	--	21.79	50.28	18.99	7.82	1.12	100.00	
Mean lengths	--	--	179	184	185	189	185	184	183

TABLE 7

Length Composition of Year Classes in Sardine Samples from the Central California Interseason Catch, 1962 (May through July)

Standard length (mm)	Year class							Totals	
	1961	1960	1959	1958	1957	1956	1955	Aged	Measured
228	--	--	--	--	--	--	--	--	1
230	--	--	--	--	--	--	--	--	--
232	--	--	--	--	--	--	--	--	--
234	--	--	--	--	--	--	--	--	1
236	--	--	--	1	--	--	--	1	3
238	--	--	--	--	1	--	--	1	5
240	--	--	--	1	--	--	--	1	3
242	--	--	--	2	--	--	--	2	7
244	--	--	--	1	--	1	--	2	3
246	--	--	--	1	--	1	--	2	8
248	--	--	--	1	1	--	--	2	9
250	--	--	--	1	3	--	--	4	12
252	--	--	--	2	--	1	--	3	8
254	--	--	--	--	--	--	--	--	8
256	--	--	--	2	1	--	--	3	11
258	--	--	--	--	1	--	--	1	11
260	--	--	--	1	--	--	--	1	6
262	--	--	--	--	--	--	--	--	1
264	--	--	--	1	--	--	--	1	2
266	--	--	--	--	--	1	--	1	1
268	--	--	--	--	--	--	--	--	--
270	--	--	--	--	--	--	--	--	--
272	--	--	--	--	--	--	--	--	--
274	--	--	--	--	--	--	--	--	1
Totals	--	--	--	14	7	4	--	25	101
Mean lengths	--	--	--	249	250	252	--	250	250

TABLE 8

Length Composition of Year Classes in Sardine Samples from the Southern California Interseason Catch, 1962 (May and June)

Standard length (mm)	Year class							Totals	
	1961	1960	1959	1958	1957	1956	1955	Aged	Measured
186		1						1	1
188									
190									
192									
194									2
196									
198									
200									
202									
204									
206			1					1	1
208									1
210									1
212									3
214					1			1	7
216				1	2			3	15
218					1	1		2	13
220				1	1			2	8
222				2	2			4	17
224				1	2			3	18
226				2	2			4	26
228				2	1			3	18
230				2	4			6	24
232					1	1		2	16
234				2	1	1		4	15
236				1	1	2		4	16
238									14
240					1			1	9
242					2			2	10
244				1				1	5
246									3
248				1		1		2	4
250									1
252									
254									1
256									1
Totals		1	1	16	22	6		46	250
Mean lengths		186	206	229	227	234		228	228

TABLE 9

Length Composition of Year Classes in Sardine Samples from the Northern Baja California Interseason Catch, 1962

Standard length (mm)	Year class							Totals	
	1961	1960	1959	1958	1957	1956	1955	Aged	Measured
164									1
166									2
168		1	1	1				3	5
170				1				1	6
172		1						1	9
174									12
176				1	1			2	11
178									10
180			2					2	11
182					2			2	18
184		2	1		1	1		5	20
186		1	1		1			3	19
188		1	1		1			3	23
190		2	4		1			7	22
192		1	1					2	19
194		1	1	2				4	33
196		2	3	1				6	35
198		3	4			1		8	42
200		1		2	1			4	46
202			3	5	1	2		11	65
204		1	4	7	4			16	70
206			3	9	1			13	73
208		1	6	7	5	1		20	75
210			9	10	7			26	76
212		1	2	7	1	1		12	67
214		1	5	6	3			15	40
216			2	1		2		5	35
218		1	1		2			4	28
220			2	2	2			6	29
222				1	1			2	16
224					1			1	14
226			1	1				2	9
228					1			1	5
230									
232				1	1			2	2
234									
236		1						1	1
238									
240									1
Totals		22	57	65	38	8		190	950
Mean lengths		197	204	207	207	205		205	203

TABLE 10

Length Composition of Year Classes in Sardine Samples from Central Baja California Interseason Catch, 1962

Standard length (mm)	Year class							Totals	
	1961	1960	1959	1958	1957	1956	1955	Aged	Measured
142			1					1	1
144									1
146									1
148									
150									3
152			1					1	1
154									2
156			1					1	4
158			3					3	10
160			1					1	11
162									24
164		1	2	2	1			6	26
166				3				3	45
168			3	6	1			10	42
170		1	4	5	1			11	52
172			3	4	2	1		10	67
174		2	5	5	3			15	82
176			3	7	4	1		15	56
178			4	6	4			14	62
180			1	3	4			8	47
182			1	4	3			8	34
184		1	1	2	2	1		7	31
186			2	2	2	2	1	9	25
188			2	2				4	9
190					1			1	10
192									1
194				1	1	1		3	5
196									4
198									3
200					1			1	8
202				1				1	7
204				1				1	2
206				2	1			3	11
208				1				1	6
210									1
212									
214									1
216						1		1	2
218									1
220									1
222				1				1	1
Totals		5	38	58	31	7	1	140	700
Mean lengths		173	171	179	180	188	186	177	176

TABLE 11

Year Class Composition of the 1962 Interseason Sardine Catch off Baja California

Lunar month	Catch		Numbers of fish in thousands by year class						
	Tons	Number	1961	1960	1959	1958	1957	1956	1955
"March"*	905	6,672	--	52	601	3,374	2,097	522	26
"April"	2,064	15,655	--	128	1,464	7,965	4,910	1,125	63
"May"	2,344	18,165	--		2,638	7,655	5,898	1,994	--
"June"	746	4,971	--	478	2,860	1,392	133	108	--
"July"	--	--	--	--	--	--	--	--	--
"August A"	61	383	--	111	199	65	8	--	--
"August B"†	133	1,024	--	215	604	176	29	--	--
Totals	‡6,253	46,870	--	984	8,366	20,607	13,075	3,749	89
Percentage		100.00	--	2.10	17.85	43.96	27.90	8.00	.19

* No samples, ages estimated from samples taken in "April".
† Excluding landings September 1–13.
‡ Includes landings from Ensenada and Cedros Island only. No samples were collected from 3,791 tons landed at Puerto Adolfo Lopez Mateos.

TABLE 12

Age and Year Class Composition of the Sardine Catch in the 1962–63 Season

	Catch		Numbers of fish in thousands by age and year class					
	Tons	Number	1	2	3	4	5	6
			1961	1960	1959	1958	1957	1956
Central California								
"August A"[1]	384	1,813	--	73	--	689	725	326
"August B"	424	2,026	--	--	--	790	912	324
"September"	297	1,624	--	--	--	682	715	227
"October"	53	257	--	--	--	116	121	20
"November"[2]	19	93	--	--	--	42	44	7
"December"[2]	16	75	--	--	--	34	35	6
"January"	6	27	6	21	--	--	--	--
Total Central California	**1,199**	**5,915**	**6**	**94**	**--**	**2,353**	**2,552**	**910**
Percentage		100.00	.10	1.59	--	39.78	43.15	15.38
Southern California								
"August B"[3]	16	87	--	--	42	39	6	--
"September"	240	1,455	--	--	698	655	102	--
"October"	485	2,888	--	--	1,415	982	462	29
"November"	192	1,179	--	--	683	448	24	24
"December"	127	708	--	--	71	524	113	--
"January"	188	1,047	--	--	356	419	220	52
"February"[4]	229	1,173	--	--	317	469	387	--
Total Southern California	**1,477**	**8,537**	**--**	**--**	**3,582**	**3,536**	**1,314**	**105**
Percentage		100.00	--	--	41.96	41.42	15.39	1.23
Total California	**2,676**	**14,452**	**6**	**94**	**3,582**	**5,889**	**3,866**	**1,015**
Percentage		100.00	.04	.65	24.79	40.75	26.75	7.02
Baja California								
"August B"	340	2,780	--	749	1,594	5	432	--
"September"	879	7,681	--	1,081	4,384	2,114	68	34
"October"[5]	240	2,139	--	203	809	1,002	--	125
"November"	870	7,114	--	1,646	4,064	1,103	279	22
"December"	828	6,476	--	1,463	2,650	1,634	558	171
"January"[6]	1,297	9,251	--	2,073	4,882	1,813	483	--
"February"	920	6,731	--	1,645	3,702	985	399	--
Total Baja California	**5,374**	**42,172**	**--**	**8,860**	**22,085**	**8,656**	**2,219**	**352**
Percentage		100.00	--	21.01	52.37	20.53	5.26	.83
Total	**8,050**	**56,624**	**6**	**8,954**	**25,667**	**14,545**	**6,085**	**1,367**
Percentage		100.00	.01	15.81	45.33	25.69	10.75	2.41

[1] August 1–14.
[2] No samples; ages estimated from "October".
[3] September 1–13; no samples; ages estimated from "September".
[4] February 9–March 2.
[5] No samples; ages estimated from "September".
[6] No samples; ages estimated from "February".
[7] Includes landings from Ensenada and Cedros Island only. No samples were collected from 2,756 tons landed at Puerto Adolfo Lopez Mateos.

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NOTES

CLEANING SYMBIOSIS IN MONTEREY BAY, CALIFORNIA

Limbaugh (1961) commented extensively on the phenomenon of cleaning symbiosis among tropical and temperate fishes. He first observed this behavior around southern California kelp beds and, to my knowledge, cleaning symbiosis north of Point Conception has not been reported. The following California marine fishes are known cleaners: Señorita, *Oxyjulis californica;* kelp perch, *Brachystius frenatus;* black perch, *Embiotoca jacksoni;* and pile perch, *Rhacochilus vacca* (Limbaugh, 1955).

On October 31, 1965, Ed Zimbelman, an experienced diver and underwater photographer, was diving over a reef near Hopkins Marine Station, Pacific Grove (lat. 36° 38′ N., long. 121° 55′ W.) where the underwater visibility ranged from 20 to 30 feet. He observed several molas, *Mola mola*, near the surface and a few dead molas on the bottom. The fish ranged between an estimated 36 and 40 inches TL. One of the molas swam over the reef, about 20 feet above the bottom, and stopped. Maintaining its position with its pectoral fins, the fish began to vibrate or "flutter" its dorsal and anal fins, and almost immediately 15 or 20 surfperch, *Phanerodon* sp. (possibly sharpnose seaperch, *P. atripes*) swam up from the reef and surrounded the mola. The perch began to pick at the mola, concentrating their efforts on the body posterior to the eye. Zimbelman attempted to approach the congregated fish in order to get photographs, but as he swam up most of the surfperch retreated. The mola remained stationary, "as if in a trance". The diver photographed the mola and the remaining surfperch for several minutes (Figure 1); then the mola suddenly seemed to realize the diver's presence and swam off.

Zimbelman observed several other molas being cleaned by surfperch during the day. On one occasion, while diving over a sunken wooden barge, he observed a school of 20 to 30 small (3- to 4-inch) rainbow seaperch, *Hypsurus caryi*, assisting in the cleaning operation.

Concentrations of molas had been noted off Monterey and Pacific Grove for about a month before Zimbelman observed the cleaning behavior. During this period he had observed dead molas on the bottom, and sea lions attacking apparently weakened molas. These observations correspond in time to the die-off of molas in Monterey Bay during the fall of 1960 (Gotshall, 1961). It is possible that the movement of molas into the Bay is, in part, due to the presence of cleaners. Limbaugh (1955) observed señoritas cleaning molas in and around the edge of kelp beds; he speculated that, "They [molas] seem to congregate purposely at the edges of the kelp beds, where the supply of jellyfish is larger and where the señoritas will eat their parasites." Limbaugh (1961) further states that "cleaning symbiosis may help to explain the range of species and the makeup of populations found in particular habitats, the patterns of local movement and migration and the natural control of disease in many fishes." The characteristics of cleaning symbiosis in the tropics differs from that observed in temperate waters.

FIGURE 1—Surfperch (*Phanerodon* sp.) cleaning molo. *Photograph by Ed Zimbelman, Nov. 1965.*

Tropical cleaners generally are not gregarious, living solitarily or in pairs, while temperate cleaners tend to be schooling fishes (Limbaugh, 1961). The observed behavior of the surfperches and molas agrees with this generalization.

These observations extend the range of cleaning symbiosis northward in California and add at least two new species of fishes to the growing list of cleaners.

Zimbelman's observations are a significant contribution to our expanding knowledge of cleaning symbiosis.

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—*Daniel W. Gotshall, Marine Resources Operations, California Department of Fish and Game, February 1966.*

FIRST RECORD OF A PACIFIC COD IN SOUTHERN CALIFORNIA WATERS

A Pacific cod, *Gadus macrocephalus* Tilesius, was caught by Jim Gagliano on March 15, 1966, while fishing aboard the sport fishing boat *Kiaora* in Santa Monica Bay, California. The fish was captured on hook and line in relatively shallow water (40 feet) in an area known as the Santa Monica Reef, lat. 33° 59.5′ N., long. 118° 30.0′ W. (about 1 mile offshore).

Pacific cod are widely distributed along the rim of the North Pacific Ocean. They have been known to occur from central California to the Bering Sea, the Sea of Okhotsk, the Sea of Japan, the Yellow Sea, and off the Aleutian and Kuril Islands (Roedel, 1953; Clemens and Wilby, 1961; Ketchen, 1961). In the eastern North Pacific Ocean they are commonly exploited off Washington, British Columbia, and Alaska (Alverson, Pruter, and Ronholt, 1961).

Six individuals, 19.75 to 25.50 inches TL, have been recorded from central California waters. Five of these were taken in deep water (80 to 90 fathoms) near Monterey Bay by commercial otter-trawl fishermen during the winters of 1951 and 1952, and the spring of 1953. The other cod, also taken by a trawl in deep water, was captured in December 1957 at lat. 35° 33′ N. near Pt. Piedras Blancas, and established the previous southern limit in the eastern North Pacific Ocean (Phillips, 1958). The Santa Monica Bay specimen thus extends the range of the species by approximately 188 nautical miles to the southeast (based on the shortest coastwise distance).

This fish (Figure 1), a mature male, 553 mm SL (623 mm TL), weighed 2,419 grams after thawing. At 24.5 inches TL, it falls within

TABLE 1

Morphometrics of the Pacific cod from Santa Monica Bay, California

Measurements	Actual in mm	Thousandths of standard length
Standard length	553	---
Total length	623	---
Maximum depth at origin of 1st dorsal	125	226
Head length	168	304
Snout	56	101
Maxillary	67	121
Interorbital (bony)	50	90
Diameter of orbit (fleshy-horizontal)	27	49
Suborbital (fleshy edge of orbit to maxillary)	31	56
Snout to 1st dorsal origin	199	360
Snout to 1st anal origin	314	568
Snout to pectoral origin	177	320
Snout to ventral origin	162	293
Length of base of dorsal fins		
1st	72	130
2nd	109	197
3rd	76	137
Length of base of anal fins		
1st	104	188
2nd	73	132
Longest 1st dorsal ray	70	127
Longest 1st anal ray	57	103
Pectoral length	90	163
Ventral length	81	147
Caudal peduncle length (ventral)	54	98

Counts	
Dorsal fins	
1st	12
2nd	14
3rd	15
Anal fins	
1st	17
2nd	15
Pectoral fin	21
Ventral fin	6
Gillrakers	
total	21
lower limb	18
angle	1
upper limb	2

FIGURE 1—Pacific cod caught in Santa Monica Bay, Californa, March 15, 1966. *Photograph by Jack W. Schott.*

the size range noted for the six central California specimens. Meristic counts and morphometrics (Table 1) compare favorably with those listed for the species (Jordan and Evermann, 1898; Clemens and Wilby, 1961). Members of the *Kiaora's* crew reported it was running milt on landing, a condition concurring with the late winter spawning reported for *G. macrocephalus* (Clemens and Wilby, 1961).

This work was performed under Dingell-Johnson Project California F-20-R, "Southern California Marine Sport Fish Survey". Grateful thanks are extended to Jack W. Schott for photographing the fish and to John E. Fitch, Herbert W. Frey, and Robert J. Lavenberg for helpful advice in preparation of this note.

The specimen was deposited in the collection of the Los Angeles County Museum of Natural History (LACM 6909-1).

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—*Leo Pinkas, Marine Resources Operations, California Department of Fish and Game, May 1966.*

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Notice is hereby given that the Fish and Game Commission shall meet on April 7, 1967, at 10:00 A.M. in Room 115, Old State Building, Los Angeles, California, to receive recommendations from its own officers and employees, from the Department of Fish and Game and other public agencies, from organizations of private citizens, and from any interested person as to what, if any, orders should be made relating to birds or mammals, or any species or variety thereof for the 1967 hunting season.

Notice is hereby given that the Fish and Game Commission shall meet at 10:00 A.M. on April 28, 1967, in the Supervisors' Chambers County Courthouse, Redding, California, for public discussion of and presentation of objections to, the proposals presented to the Commission on April 7, 1967, and after consideration of such discussion and objections the Commission shall publicly announce the regulations it proposes to make relating to birds or mammals, or any species or variety thereof, for the 1967 hunting season.

Notice is hereby given that the Fish and Game Commission shall meet on May 26, 1967, at 10:00 A.M., in the Main Floor Auditorium, Resources Building, 1416 Ninth Street, Sacramento, California, to hear and consider any objections to its determinations or proposed orders in relation to birds and mammals for the 1967 hunting season, such determinations resulting from hearing held on April 28, 1967. This notice is published in accordance with the provisions of Section 206 of the Fish and Game Code.

Fish and Game Commission
Monica O'Brien
Secretary to the Commission

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